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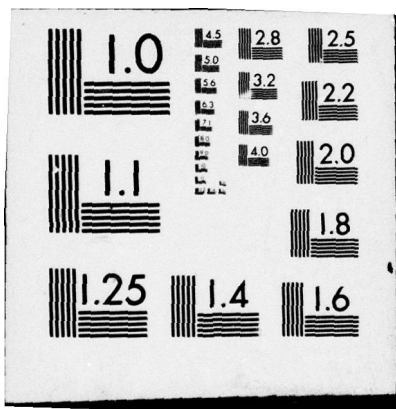
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AQUATIC PLANT CONTROL PROGRAM
TECHNICAL REPORT 13. AQUATIC USE PATTERN
FOR DIQUAT FOR CONTROL OF EGERIA AND HYDRILLA

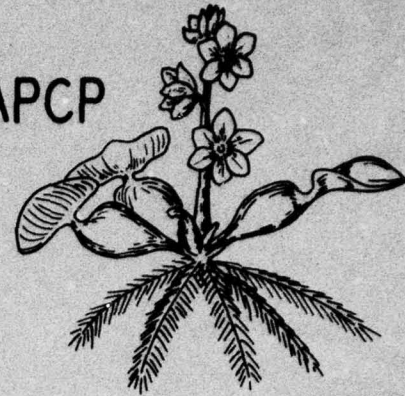
ARMY ENGINEER WATERWAYS EXPERIMENT STATION
VICKSBURG, MISSISSIPPI

SEPTEMBER 1976

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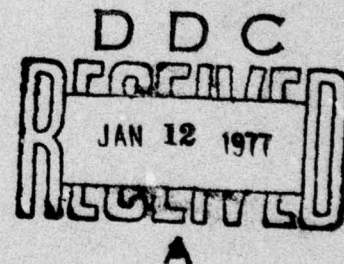


AQUATIC PLANT CONTROL PROGRAM

Technical Report 13

**AQUATIC USE PATTERN FOR DIQUAT
FOR CONTROL OF EGERIA AND HYDRILLA**

ORIGINAL CONTAINS COLOR PLATES: ALL DDC
REPRODUCTIONS WILL BE IN BLACK AND WHITE



SPONSORED BY: Office, Chief of Engineers
U. S. Army

PUBLISHED BY: U. S. Army Engineer
Waterways Experiment Station
Vicksburg, Mississippi



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) It has been found that diquat and diquat plus copper can be used effectively to control egeria and hydrilla. Repeat applications are necessary for proper maintenance. Herbicide residues are dissipated in 1-3 days, depending upon the specific situation. Results indicate that no residues are to be found in crops irrigated with water treated with diquat at the levels used for the control of obnoxious aquatic vegetation.		

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PREFACE

The term "weed" has been defined as any plant growing to the detriment of the intended use or the disfigurement of the place. Aside from nuisance conditions, control of aquatic weeds in canals, drains, ditches, lakes, shorelines, and reservoirs is found necessary in order to obtain the full benefits from irrigation systems, recreational areas, and sources of potable water.

A practical solution to the problem of efficient and economic control of various kinds of weeds is the use of herbicides which may be classed as phytotoxic chemicals used for the killing, inhibiting, or stunting the development or growth of plants. However, experience has indicated that chemicals are not totally effective for the control of all types of weeds and, consequently, attention has been directed to the development of selective herbicides. The use of these selective herbicides, singly or in combination, has found acceptance as a supplement to improved cultural management practices.

There are few instances in which the efficiency of chemicals has not exceeded that of presently available alternatives for aquatic plant control. Chemicals, however, are difficult to confine to specific areas, and in some situations, treatment of a body of water results in temporary removal of nontarget species. In spite of current efforts to use alternative control measures, chemical control methods remain a necessary part of any realistic vegetation management program; moreover, an integrated system must utilize specific herbicides for specific target species.

This report is a summary of the Corps of Engineers cooperative research (1969-1974) with the U. S. Department of Agriculture, the University of Southwestern Louisiana, and the Virginia Commission of Game and Inland Fisheries for Chemical Control of *Egeria* and *Hydrilla*.

Edward O. Gangstad MASCE.

Contents

	<u>Page</u>
Preface	2
Conversion Factors, U. S. Customary to Metric (SI)	
Units of Measurement	4
Aquatic Plant Control Program	5
Interagency Technical Advisory Committee	5
Efficacy and Residues of Diquat	5
Chemical Control of Egeria	6
Aquatic Weed Control in Small Reservoirs	6
Environmental Assessment	7
APPENDIX A: LETTER OF AUTHORITY, AGENDA FOR THE MEETING, AND LIST OF ATTENDEES	A1
APPENDIX B: PROPOSED LABEL FOR CORPS OF ENGINEERS USE AND AREAS OF INTENDED USE	B1
APPENDIX C: EFFICACY AND RESIDUES OF DIQUAT APPLIED FOR CONTROL OF EGERIA AND HYDRILLA, by Robert D. Blackburn and Edward O. Gangstad	C1
APPENDIX D: GREENHOUSE STUDIES OF THE GROWTH AND REPRODUCTION OF <u>EGERIA Densa</u> by J. A. Foret, J. R. Barry, S. J. Langlinais, S. L. Solymosy, and D. P. Viator	D1
APPENDIX E: AQUATIC WEED CONTROL IN SMALL RESERVOIRS WITH DIQUAT, by Richard R. Yeo, Nathan Dechoretz, P. A. Frank, and Edward O. Gangstad	E1
APPENDIX F: FINAL ENVIRONMENTAL STATEMENT FOR WALKER DAM IMPOUNDMENT, AQUATIC PLANT CONTROL PROJECT, NEW KENT COUNTY, VIRGINIA	F1

Conversion Factors, U. S. Customary to Metric (SI)
Units of Measurement

U. S. customary units of measurements used in this report can be converted to metric (SI) units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	2.54	centimetres
feet	0.3048	metres
square feet	0.092903	square metres
acres	0.40468	hectares
quarts (U. S. liquid)	0.000947	cubic metres
gallons	3.78533	litres
acre-inches	0.102790	cubic metres
pounds	0.45359237	kilograms
pounds (force) per square inch	6894.757	pascals
pounds per acre	1.128	kilograms per hectare
miles per hour (U. S. statute)	1.609344	kilometres per hour
gallons per acre	9.353	litres per hectare
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin readings, use: $K = (5/9)(F - 32) + 273.15$.

AQUATIC USE PATTERN FOR DIQUAT FOR CONTROL
OF EGERIA AND HYDRILLA

by

Edward O. Gangstad*

Aquatic Plant Control Program

1. As authorized under the River and Harbor Act of 1965, the Aquatic Plant Control Program is designed to deal with infestations of obnoxious aquatic plants of major economic significance which invade navigable waters and cause problems in the navigation and related uses of water. Initial planning for control of these plants include:

(a) general survey of problem areas, (b) research involving control of the aquatic plant, and (c) development or implementation of suitable methods of operational procedure.

Interagency Technical Advisory Committee

2. A meeting of the committee was held 8-10 April 1970 at Tallahassee, Florida, to review current research projects, to discuss new research proposals, and to report on aquatic plant problems, including problems with egeria and hydrilla. The letter of authority, agenda for the meeting, and list of attendees are given in Appendix A. The proposed label for Corps of Engineers use, areas of intended use, and information on the physical, chemical, and biological characteristics of diquat are given in Appendix B.

Efficacy and Residues of Diquat

3. It has been found that diquat and diquat plus copper can be used to effectively control egeria and hydrilla. Repeat applications are necessary for proper maintenance. Herbicide residues are dissipated

* Botanist, Office, Chief of Engineers, Washington, D. C.

in 1-3 days, depending upon specific situations. Details of the study are given in Appendix C.

Chemical Control of Egeria

4. A study of the results of laboratory and field investigations of growth and reproduction of Egeria densa and its response to herbicides is presented in Appendix D. The weed studied in this project was thought to be Elodea densa, but a critical review of the literature and herbaria have definitely established it as Egeria densa.

5. Egeria densa produces only male flowers in Louisiana and reproduces vegetatively only from stem tips. Following extensive greenhouse, small-pool and small-scale field trials, it was found that the most efficient chemicals for control of Egeria densa were diquat, komine, and combinations of diquat and komine or K-lox. Retreatment may be necessary the first year, followed by annual chemical treatments to maintain satisfactory chemical control of the aquatic weed pest.

Aquatic Weed Control in Small Reservoirs

6. Diquat has been one of the more effective herbicides for control of aquatic weeds in small reservoirs. Treatment rates range from 0.25 to 1.5 ppmw, depending on the susceptibility of the weeds treated. For spot treatments, the rates are generally higher to insure adequate control. Combinations with copper sulfate are successful but must be used with caution to prevent killing of fish.

7. Results of detailed studies indicate that no residues are to be found in crops irrigated with diquat at levels normal for treatment of obnoxious aquatic vegetation. Diquat is dissipated rapidly from treated water, and herbicide residues are not commonly detectable after 3 days. Details of the study are given in Appendix E.

Environmental Assessment

8. Chickahominy Reservoir (Walker Dam Impoundment), a 1093-hectare water supply reservoir in Tidewater, Virginia, was treated with diquat and endothall to control Egeria densa in 1969 and a second treatment was planned for 1972. It appears that the favorable environmental effects greatly exceed the adverse effects. The final statement was filed in October 1972 with the Council on Environmental Quality. Details of the study are given in Appendix F.

APPENDIX A

LETTER OF AUTHORITY, AGENDA FOR THE
MEETING, AND LIST OF ATTENDEES



IN REPLY REFER TO:

ENG CW-PV

18 March 1970

LETTER OF AUTHORIZATION
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20314

Arrangements have been completed for a meeting of the Interagency Research Advisory Committee for our Aquatic Plant Control Program to be held in the Mezzanine Auditorium of the Federal Savings and Loan Association, Tallahassee, Florida, 8-10 April 1970, beginning at 1:45 p.m.

The agenda for this meeting is planned to provide an opportunity for professional presentation of current research projects and to review research proposals under consideration within the limits of the 1971 budget.

This letter will confirm our invitation to attend the meeting and to participate in the discussions. Reservations are being made at the Holiday Inn in Tallahassee, Florida, for Wednesday night, 8 April 1970, and at the Morgan Motel, Chattahoochee, Florida, for Thursday night, 9 April 1970. Please advise us if you have other arrangements.

Sincerely yours,

1 Incl
Agenda

LOUIS G. FEIL
Chief, Planning Division
Civil Works

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AGENDA FOR THE MEETING

INTERAGENCY RESEARCH ADVISORY COMMITTEE MEETING
AQUATIC PLANT CONTROL PROGRAM

Mezzanine Auditorium
Federal Savings and Loan Association
Tallahassee, Florida

<u>Time</u>	<u>Topics and Events</u>
<u>Wednesday, 8 April 1970</u>	
1:45-2:00	Introductions (Mobile District)
2:00-2:15	Welcome Address (Mobile District)
2:15-2:30	Corps of Engineers APC Program - Hal Blakey, Chief, Environmental Branch, OCE, Washington, D. C.
2:30-2:40	Coffee Break
2:40-3:00	Agriculture - Dr. Bill Ennis, Chief, Crops Protection Branch, USDA, Beltsville, Maryland
3:00-3:20	Entomology - Dr. Reece Sailer, Insect Introduction and Control Branch, USDA, Beltsville, Maryland
3:20-3:40	Fisheries Research - Dr. Willis King, Chief, Fisheries Services, USDI, Washington, D. C.
3:40-4:00	Biomass Concepts - Dr. J. M. Laurence, Professor of Fisheries Research, Auburn University, Alabama
4:00-4:20	Herbicide Residues - Dr. Charles Walker, Chief, Pest Control Research Branch, USDI, Washington, D. C.
7:00-9:00	Discussion of Research Proposals (Committee only)
<u>Thursday, 9 April 1970</u>	
8:20-8:40	Slow Release Herbicides - N. F. Cardarelli, Associate Professor of Biology, Akron University, Ohio
8:40-9:00	Phytozone Research - Dr. Kerry Steward, Plant Physiolo- gist, USDA, Fort Lauderdale, Florida
9:00-9:20	Laser Research - John Erhlich, Research Physicist, Redstone Arsenal, Huntsville, Alabama
9:20-9:40	Cytological Studies - Dr. Richard Couch, Professor of Botany, Athens College, Athens, Alabama
(Continued)	

<u>Time</u>	<u>Topics and Events</u>
<u>Thursday, 9 April 1970 (Continued)</u>	
9:40-10:00	Coffee Break
10:00-10:20	Insect Introductions - Dr. Reece Sailer, Research Entomologist, USDA, Albany, California
10:20-10:40	Herbivorous Fish - Robert Blackburn, Biologist, USDA, Fort Lauderdale, Florida
10:40-11:00	Aquatic Plant Pathogens - Dr. F. William Zettler, Pathology Department, University of Florida, Gainesville, Florida
11:00-11:30	Discussion of Field Trip (SAD and Mobile District)
1:30-4:30	Field Trip to Chattahoochee, Florida
<u>Friday, 10 April 1970</u>	
7:30-12:00	Boat Trip on Lake Seminole, Florida
1:30-3:00	Return Trip to Tallahassee, Florida

LIST OF ATTENDEES

CORPS OF ENGINEERS INTERAGENCY RESEARCH ADVISORY COMMITTEE
MEETING - AQUATIC PLANT CONTROL PROGRAM

8-10 April 1970 - Tallahassee, Florida,
and Lake Seminole, Florida and Georgia

<u>Name</u>	<u>Title</u>	<u>Organization and Location</u>
Gordon Mobley	Chief, APC Engr Division	C of E, Jacksonville, Fla.
Emanuel A. Drago	Chief, Environ. & Resources Branch	C of E, Mobile District
Charles F. Zeiger	Chief, APC Section, Operations	C of E, Jacksonville District
John W. Woods	Chief, Fisheries Division	Florida Game & Fresh Water Fish Commission
P. A. Barthel	Chief, Atlanta Tox, Branch	FDA, Atlanta, Ga.
Robert Blackburn	Botanist	ARS, Fort Lauderdale, Fla.
W. B. Ennis, Jr.	Chief, Crops Protection Research Branch	ARS, USDA, Beltsville, Md.
Kerry Steward	Plant Physiologist	USDA, ARS, Fort Lauderdale, Fla.
R. I. Sailer	Chief, IIPi Research Branch	ARS, USDA, Beltsville, Md.
Neal R. Spencer	Research Entomologist	USDA-ARS-ENT Bio Control Gainesville, Fla.
Nate Cardarelli	Associate Professor	University of Akron
Richard Couch	Professor of Biology	Athens College, Athens, Ala. 35611
William W. Young	LTC, Chief Entomology	USA Environmental Health
Harold L. Blakey	Chief, Environmental Branch	ENG CW-PV, OCE, Washington, D. C.
Edward O. Gangstad	Chief, Aquatic Weed Control Section	ENG CW-PO, OCE, Washington, D. C.

(Continued)

List of Attendees (Continued)

<u>Name</u>	<u>Title</u>	<u>Organization and Location</u>
W. H. Dvorachek	Assistant Chief, Project Operation Branch	ENG CW-0, OCE, Washington, D. C.
Willis King	Chief, Division of Fishery Service	BSF&W, Washington, D. C.
Charles R. Walker	Chief, Branch of Pest Control Research, Division Fish Research	BSF&W, Washington, D. C.
John M. Lawrence	Professor of Fisheries	Auburn University, Auburn, Ala.
F. W. Zurburg	University Southwestern Louisiana	Lafayette, La.
W. W. Barnes	Assistant Chief, Envir. Biology Branch	TVA, Muscle Shoals, Ala.
F. William Zettler	Department of Plant Pathology	University of Florida
A. N. Williamson	Acting Chief, Remote Sensing Section	USAE Waterways Experiment Station, Vicksburg, Miss.
Thomas N. Sargent (for Dr. H. P. Nicholson)	Assistant Chief, Industrial Pollution Control	USDI, FWPCA, Athens, Ga.
Katherine Walker	Biologist, Staff	University of Akron, Akron, Ohio
Willey C. Durden	Research Technician	C. R., U. S. Plant Int. Station, Savannah, Ga.
George W. Allen	Biologist	C of E, Mobile District
D. C. Vickers	Biologist Technician	C of E, Lake Seminole
J. H. Bradley	Civil Engineer	C of E, Charleston District
Otis H. Johnson, Jr.	Agronomist	C of E, Wilmington District
H. T. DeRigo	Biologist	C of E, Savannah District
Clifford J. Novosad	Agronomist	C of E, Galveston District
Donald J. Chatelain	Civil Engineer	C of E, Galveston District

(Continued)

List of Attendees (Concluded)

<u>Name</u>	<u>Title</u>	<u>Organization and Location</u>
William E. Thompson	Chief, Aquatic Gr. Control, Section	C of E, New Orleans District
J. R. Griffith	Chief, Operations Branch	C of E, LMVD
David R. Bayne	Research Assistant	Auburn University
A. K. Gholson, Jr.	Assistant Research Manager	C of E, Lake Seminole
F. J. Cuscio	Chief, Environmental Engineering	SAD, C of E, Atlanta, Ga.
J. J. Raynes	Assistant Chief, Land Planning Section	SAD, C of E, Atlanta, Ga.
John Erhlich	Research Physicist	Redstone Arsenal, Hunts- ville, Ala.

APPENDIX B

PROPOSED LABEL FOR CORPS OF ENGINEERS
USE AND AREAS OF INTENDED USE

PROPOSED LABEL FOR CORPS OF ENGINEERS
USE AND AREAS OF INTENDED USE

Proposed Label for Corps of Engineers Use

1. The proposed label for the Corps of Engineers use is presented in Figure B1.

DIQUAT AQUATIC HERBICIDE	
Active Ingredient	By Weight
Diquat dibromide [6,7-dihydrodipyrdo (1,2-a:2',1'-c) pyrazidiinium dibromide]	35.3%
Inert Ingredients	64.7%
Contains 2 lb Diquat cation per gal as 3.73 lb salt per gal	
KEEP OUT OF THE REACH OF CHILDREN	
Manufactured for the Corps of Engineers Aquatic Plant Control Program	

Figure B1a. Proposed registration label

DIRECTIONS FOR USE

This product is formulated for use on ponds, lakes, marshes, reservoirs, bayous, and other quiescent or slowly moving bodies of water for control of obnoxious aquatic plants.

Floating and Emerged Weeds

<u>Foliage Spray Treatments</u>	<u>Amount per Surface Acre</u>
Salvinia (<u>Salvinia rotundifolia</u>)	2-3 qt
Water hyacinth (<u>Eichhornia crassipes</u>)	2-3 qt
Water lettuce (<u>Pistia stratiotes</u>)	2-3 qt

FOLIAGE SPRAY TREATMENTS should be applied in sufficient water (150-200 gal per surface acre) to thoroughly wet foliage. FOR CONTROL OF WATER LETTUCE aerial applications using 7-1/2 gal of water per surface acre may be used. As the season progresses and vegetation increases in mass, the higher dosages indicated should be used and more uniform distribution is necessary.

Submersed Weeds

<u>Water Treatments</u>	<u>Amount per Surface Acre</u>
Algae (<u>Spirogyra</u> and <u>Pithophora</u> spp)	4 qt
Bladderwort (<u>Utricularia</u> spp)	4-8 qt
Naiad (<u>Najas</u> spp)	4 qt
<u>Egeria densa</u>	4-8 qt
<u>Hydrilla verticillata</u>	4-8 qt

WATER TREATMENTS may be applied by injecting diquat below the water surface, or by pouring diquat directly from the container into the water while moving slowly over the water surface in a boat.

Figure Blb. Directions for use

CAUTIONS

SAFETY

The operator should avoid contact of the herbicide with the skin, eyes, or clothing and avoid spray drift onto susceptible plants such as cotton, beans, peas, most vegetables, ornamentals, and trees. Coarse sprays or other means of reducing spray drift should be used where the situation is critical.

WARNING

Herbicide may be fatal if swallowed, inhaled, or absorbed through skin. Prolonged skin contact will cause severe irritation. Do not get concentrate material on skin, eyes, or clothing. Repeated contact with skin may increase danger of absorption. Symptoms of injury may be delayed. In case of accidental skin contact, wash immediately with water; remove clothing and wash skin where necessary. For eyes, wash thoroughly with water and get medical attention. Wear face shield, rubber gloves, and rubber apron when handling concentrate. In order to avoid nasal, throat and respiratory tract irritation, do not breathe spray mist. When spraying or when contacting sprayed vegetation wet with spray, dew, or rain, wear waterproof footwear and clothing.

STORAGE AND DISPOSAL

Do not store this product with fertilizers, seeds, insecticides, or fungicides. Do not reuse empty containers or dispose of them by burning in an open incinerator. Destroy them by puncturing with holes and burying in the ground to a depth of at least 18 in. in an area which will not contaminate an above-ground or below-ground water supply and is not accessible to livestock.

WIND VELOCITY

Do not spray by boat when the wind velocity is above 10 mph or by airplane when the wind velocity is above 5 mph. Avoid spraying when the direction of the wind is likely to bring spray drift toward desirable vegetation.

OPEN-WATER AREAS

To reduce contamination and prevent injury to fish, avoid spraying open-water areas that are not infested with obnoxious plants. Do not apply to muddy water or agitate water excessively during application.

OXYGEN DEPLETION

To avoid injury or death of fish from oxygen deficiency or release of toxic materials from decomposing vegetation, do not treat more than one-half of a lake or pond at one time.

UNTREATED BUFFER STRIP

In open water, leave buffer strips at least 100 ft wide, and delay treatment of these strips 4-5 weeks or whenever the dead vegetation has decomposed.

FISH TOXICITY

Do not use fish for food for 14 days after treatment or until an approved analysis shows that the fish flesh does not contain more than the equivalent of 0.1 ppm diquat ion.

DOMESTIC USE

Delay use of the treated water for livestock watering and other domestic uses for 14 days after treatment unless an approved analysis shows the water does not contain more than 0.1 ppm diquat ion.

IRRIGATION

Delay use of the treated water for irrigation for 14 days after treatment unless an approved analysis shows that the water does not contain more than 0.1 ppm diquat.

Figure B1c. Cautions

Areas of Intended Use

Location and authorization

2. The project is located along the waterways and streams of the Gulf and South Atlantic States of Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas; South Atlantic Division, Atlanta, Georgia; Lower Mississippi Valley Division, Vicksburg, Mississippi; and Southwestern Division, Dallas, Texas. Areas of intended use are given in Table B1. The project is authorized by the 1958 River and Harbor Act, as amended in 1965.

Purpose

3. The purpose of the project is to obtain progressive control and eradication of water hyacinth, alligator weed, and other obnoxious and detrimental aquatic plant growths from the navigable waters, tributary streams, connecting channels, and other allied waters of the Gulf and South Atlantic States listed in paragraph 2 and to research the most effective control and eradication measures.

Justification

4. Obnoxious and detrimental aquatic plant growths, including water hyacinth and alligator weed, are well established in many watercourses of the Gulf and South Atlantic States and have spread markedly in recent years. The belt of damaging infestation extends across the Southern States from North Carolina to Texas and from the saltwater line on the south to the area of intense winter freezing to the north. Generally after rains and floods, large masses of aquatic plants are carried downstream into the principal waterways. Clogging of waterways has become very extensive, often blanketing a long stretch of a watercourse from bank to bank. The thick mats formed by the growths clog vessel propellers and rudders, cause jams against bridges, and increase navigation hazards by making floating logs and snags. Additionally, these thick growths retard runoff, impede drainage, increase flooding of low cultivated lands, block pump intakes, adversely affect fish and wildlife by destroying their food supply and depleting the dissolved oxygen in the water, and constitute a menace to public health by

increasing the malaria hazard and polluting public water supplies from plant decomposition. The control and eradication of these pesty aquatic growths will prevent damages estimated at several millions of dollars annually.

Table B1

Areas of Intended Use

Treatment Areas	Problem Plants, Estimated Acres										Control in Interests of					Fish & Wildlife
	Hyacinth	Hydrilla	Elo-dea	Water Lettuce	Alligator Weed	Milfoil	Southern Maid	Cattail	Submersed Aquatics	Navigation	Flood Control	Agriculture	Public Health			
South Atlantic Division, Jacksonville District																
Upper St. Johns R.																
Headwaters to Highway 50	6,000	0	--	300	300	--	--	--	--	X*	Y**	Y	X	X	X	
Highway 50 to Lake George	15,000	5,000	--	200	800	--	--	--	--	X	Y	Y	X	X	X	
Withlacoochee R.	10,000	3,000	--	700	1,500	--	--	--	--	X	Y	Y	--	X	X	
Oklawaha R.	6,000	50+	--	0	600	--	--	--	--	X	Y	Y	--	X	X	
Hillsborough R.	5,000	++	--	1,500	50	--	--	--	--	Y	X	--	X	Y	Y	
Kissimmee R.	6,000	250	--	450	75	--	--	--	--	X	X	Y	--	X	X	
Lake Okeechobee tributaries	5,000	50+	--	200	40	--	--	--	--	X	X	X	--	Y	Y	
Peace R.	800	++	--	0	50	--	--	--	--	--	Y	Y	X	X	X	
Caloosahatchee R.	3,000	0	--	200	120	--	--	--	--	X	X	X	X	Y	X	
Myakka R.	1,000	0	--	0	0	--	--	--	--	Y	Y	Y	X	X	X	
Lake Istokpoga and tributaries	3,000	0	--	0	50	--	--	--	--	--	X	X	--	Y	Y	
Gulf Coast																
Yankeetown to Tampa Bay	600	4,500	--	+	0	--	--	--	--	X	--	--	--	X	X	
Suwannee R.	1,000	0	--	0	400	--	--	--	--	X	--	--	--	X	X	
Santa Fe R.	200	0	--	0	5	--	--	--	--	--	--	--	--	X	X	
Alafia, Manatee, and Little Manatee R.	2,000	0	--	0	600	--	--	--	--	--	--	--	X	Y	Y	
Manatee R.																
East Coast--Stuart to Cocoa	500	0	--	0	--	--	--	--	--	--	--	--	--	X	Y	
Aucilla-Wacissa R.	200	225+	--	0	0	--	--	--	--	--	--	--	--	Y	Y	
Waccasassa R.	50	0	--	0	0	--	--	--	--	--	--	--	--	Y	Y	
South Atlantic Division, Savannah District																
Satilla R.	75	--	--	--	1,000 (mainly in rice fields)	--	--	--	--	--	--	X	--	X	--	
Savannah R.																
Stevens Creek Reservoir, Savannah R.	10	--	--	--	150	--	--	--	--	X	--	--	--	--	--	
	--	--	200	--	--	--	--	--	--	X	--	--	--	--	--	
TOTAL ACREAGE	85	200	200	--	1,150	--	--	--	--	--	--	--	--	--	--	

(Continued)

(Continued)

Note: Field operations to be conducted on hyacinths. Water lettuce, cattail, and other grasses to have "spot treatment" only when necessary for more effective control of hyacinth.

* X denotes major priority.

** Y denotes minor priority.

+ Egeria.

++ No estimate available.

+ About 9,000 acres of Eurasian water milfoil in the Gulf Coastal area.

(Sheet 1 of 4)

Table B1 (Continued)

Treatment Areas	Problem Plants, Estimated Acres							Control in Interests of					Fish & Wildlife	Recreation		
	Hyacinth	Hydrilla	Elo-dea	Water Alligator			Southern Naiad	Cat-tail	Submersed Aquatics	Navigation	Flood Control	Agriculture			Public Health	
				Lettuce	Weed	Milfoil										
South Atlantic Division, Charleston District																
Pee Dee R.	--	--	--	--	--	200	--	--	--	--	X	Y	Y	Y	Y	Y
Little Pee Dee R.	--	--	--	--	--	450	--	--	--	--	X	Y	Y	Y	X	X
Black R.	--	--	--	--	--	4,000	--	--	--	--	X	Y	Y	Y	X	X
Mingo Creek	--	--	--	--	--	250	--	--	--	--	X	Y	Y	Y	Y	X
Wateree R.	--	--	--	--	--	100	--	--	--	--	X	Y	Y	Y	X	X
Congaree R. and tributaries	--	--	--	--	--	500	--	--	--	--	X	Y	Y	Y	X	X
Lakes Marion and Moultrie	--	--	--	--	--	4,000	--	--	--	--	Y	Y	Y	X	X	X
Santee R. below Santee Dam	--	--	--	--	--	800	--	--	--	--	X	Y	Y	Y	Y	X
Cooper R.	--	--	--	--	--	5,600	--	--	--	--	X	Y	Y	Y	X	X
Goose Creek Reservoir	--	--	--	--	--	1,800	--	--	--	--	Y	Y	Y	X	X	X
Ashley R.	--	--	--	--	--	5,200	--	--	--	--	X	Y	Y	Y	Y	X
Edisto R.	--	--	--	--	--	5,610	--	--	--	--	X	X	Y	Y	X	X
Ashepoo R.	--	--	--	--	--	250	--	--	--	--	X	Y	Y	Y	Y	Y
Combabee R.	--	--	--	--	--	200	--	--	--	--	X	Y	Y	Y	Y	Y
Salkehatchie R.	--	--	--	--	--	300	--	--	--	--	X	Y	Y	Y	Y	Y
Little Salkehatchie R.	--	--	--	--	--	250	--	--	--	--	X	Y	Y	Y	Y	Y
Coosawhatchie R.	--	--	--	--	--	200	--	--	--	--	X	Y	Y	Y	Y	Y
TOTAL ACREAGE	--	--	--	--	--	29,710	--	--	--	--	--	--	--	--	--	--
South Atlantic Division, Wilmington District																
Wilmington Area	--	--	††	--	--	35§	--	100	--	--	--	Y	--	Y	X	X
Onalow County	--	--	--	--	--	9§	--	--	--	--	--	Y	--	Y	X	X
Martin County	--	--	--	--	--	10§	--	--	--	--	--	Y	--	Y	X	X
Washington County	--	--	--	--	--	20§	--	--	--	--	--	Y	--	Y	X	X
Tyrell County	--	--	--	--	--	25§	--	--	--	--	--	Y	--	Y	X	X
Perquimans County	--	--	††	--	--	1§	--	--	--	--	--	Y	--	Y	X	X
Pasquotank County	--	--	--	--	--	8§	--	--	--	--	--	Y	--	Y	X	X
Edgecombe County (Tar River)	--	--	††	--	--	--	--	--	--	--	--	--	--	--	--	--
Currituck--Dare Counties (Currituck Sound)	--	--	--	--	--	12,000	--	--	--	--	--	--	--	--	--	--
Dare County (East Lake)	--	--	--	--	--	75	--	--	--	--	--	--	--	--	--	--
Tyrell County (Alligator Creek)	--	--	--	--	--	60	--	--	--	--	--	--	--	--	--	--
Chowan County	--	--	††	--	--	--	--	--	--	--	--	--	--	--	--	--
Bertie County	--	--	††	--	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL ACREAGE	--	--	--	--	--	108§	12,135	100	--	--	--	--	--	--	--	--
(Continued)																

(Continued)

†† Known infestations; no estimate of acres available.

§ Acreage indicated is that under treatment.

(Sheet 2 of 4)

Table B1 (Continued)

Treatment Areas	Problem Plants, Estimated Acres										Control in Interests of				
	Hyacinth	Hydrilla	Elo-dea	Water Lettuce	Alligator Weed	Milfoil	Southern Naiad	Cattail	Submersed Aquatics	Navigation	Flood Control	Agriculture	Public Health	Wildlife	Fish & Recreation
South Atlantic Division, Mobile District															
Florida															
Lake Grassy--Munson--Lake Jackson	300	--	--	--	--	--	--	--	--	--	X	--	Y	Y	X
Ochlocknee R. (Lake Talquin and stream areas, Crooked River)	600	200	200	--	800	--	--	--	200	X	--	--	Y	X	X
Apalachicola River Basin (Lake Mimico)	2,000	500	500	--	250	--	--	300	--	X	--	--	Y	X	X
Lynn Haven Lake	10	--	--	--	--	--	--	7	--	--	--	--	X	--	--
Bayou Chico	100	--	--	--	550	--	--	--	--	X	--	--	X	--	--
Georgia															
Flint R.	95	--	--	--	20	--	--	--	--	Y	X	--	Y	Y	X
Alabama															
Ala.-Coosa Basin (Blue Girth Creek)	80	--	--	--	--	--	--	--	--	X	Y	--	Y	Y	X
Tombigbee--Warrior River Basin	50	--	--	--	--	--	--	--	--	X	Y	--	Y	Y	Y
Mobile Delta and Dog River	--	1,500	1,500	--	1,200	--	--	--	300	X	Y	--	Y	X	X
Mississippi															
Pascagoula River Basin and Coastal Area	++	++	++	--	++	--	--	--	--	X	Y	--	X	X	X
Louisiana															
Pearl River Basin	200	--	--	--	400	--	--	--	500	X	X	--	Y	X	X
TOTAL ACREAGE	3,435	2,200	2,200	--	3,220	--	--	307	1,000						
Lower Mississippi Valley Division, New Orleans District															
Area I - Ponchartrain	250	--	--	--	950	--	--	--	450	X	X	X	Y	X	X
Maurepas Area															
Area II - Plaquemine	1,000	--	--	--	525	--	--	--	3,800	X	X	X	Y	X	X
Waterway Area															
Area III - Atchafalaya Area	6,500	--	--	--	3,100	--	--	--	1,900	X	X	X	Y	X	X
Area IV - Teche Area	850	--	--	--	500	--	--	--	2,600	X	X	X	Y	X	X
Area V - Central Louisiana Area	6,000	--	--	--	900	--	--	--	15,250	X	X	X	Y	X	X
Area VI - North Louisiana Area	14,000	--	--	--	2,300	--	--	--	47,500	X	X	X	X	X	X

(Continued)

++ Known infestations; no estimate of acres available.

§§ Elodea and water milfoil are included with all other underwater vegetation under this heading.

(Sheet 3 of 4)

Table B1 (Concluded)

Treatment Areas	Problem Plants, Estimated Acres										Control in Interests of					Fish & Wildlife	Recreation	
	Hyacinth	Hydrilla	Elodea	Water Lettuce			Alligator Weed	Milfoil		Southern Nalad	Cat-tail	Submersed Aquatics	Navigation	Flood Control	Agriculture			Public Health
				Lower Mississippi Valley Division	Valley Division	New Orleans District		(Continued)										
Area VII - South Louisiana Area	8,400	--	--	--	--	--	3,000	--	--	--	--	5,000§§	X	X	X	X	X	
Area VIII - Adjacent Swamp Area	25,000	--	--	--	--	--	25,000	--	--	--	--	10,000§§	--	X	X	X	X	
TOTAL ACREAGE	62,000	--	--	--	--	--	36,275	--	--	--	--	86,500§§						
Southwestern Division, Galveston District																		
Nueces	50	--	--	--	--	--	0	0	--	--	--	--	X	X	X	X	X	
Guadalupe	2,000	--	--	--	--	--	0	0	--	--	--	--	Y	X	X	Y	X	
North Coastal	3,000	--	--	--	--	--	2,000	0	--	--	--	--	Y	X	X	Y	X	
Sabine	5,000	--	--	--	--	--	1,500	477	--	--	--	--	X	X	Y	--	X	
Trinity	2,500	--	--	--	--	--	3,000	0	--	--	--	--	--	X	X	Y	Y	
Neches	800	--	--	--	--	--	400	1,500	--	--	--	--	X	Y	Y	Y	X	
Cypress	100	--	--	--	--	--	0	5,000	--	--	--	--	X	Y	Y	X	X	
South Coastal	500	--	--	--	--	--	0	0	--	--	--	--	Y	X	X	Y	X	
San Jacinto	700	--	--	--	--	--	1,500	0	--	--	--	--	--	X	X	Y	X	
Rio Grande	5	--	--	--	--	--	0	0	--	--	--	--	Y	Y	Y	Y	X	
Colorado	0	--	--	--	--	--	0	2,875	--	--	--	--	--	--	--	--	--	
Brazos	0	--	--	--	--	--	0	200	--	--	--	--	--	--	X	X	--	
TOTAL ACREAGE	14,655	--	--	--	--	--	8,400	10,052	--	--	--	--	--	--	--	--	--	

§§ Elodea and water milfoil are included with all other underwater vegetation under this heading.

(Sheet 4 of 4)

APPENDIX C

EFFICACY AND RESIDUES OF DIQUAT APPLIED
FOR CONTROL OF EGERIA AND HYDRILLA

by

Robert D. Blackburn
Edward O. Gangstad

EFFICACY AND RESIDUES OF DIQUAT APPLIED
FOR CONTROL OF EGERIA AND HYDRILLA*

by

Robert D. Blackburn and Edward O. Gangstad**

Introduction

Obnoxious aquatic plants

1. The rapid proliferation of certain aquatic plants in lakes and waterways has greatly interfered with human activities. When these plants are present in sufficient quantity, they limit navigation, recreation, fish production, drainage, public health, and property values. However, less aggressive aquatic plants provide shelter for fish, serve as a source of oxygenation for water, and contribute staple food for fish and waterfowl.¹⁻⁵

Description of Plants

2. Egeria densa Planch is a monocotyledonous, submersed hydrophyte in the family Hydrocharitaceae. It is a perennial, slender-stemmed, branching plant with whorled leaves and slender, unbranched, fibrous roots. Egeria has the ability to exist as a free-floating plant. The lowest leaves are opposite, or in whorls of three, and the middle and upper leaves are in whorls of four to eight. Leaves are 3-5 mm wide, up to 40 mm long, closely spaced, and sessile, with serrated edges. Each leaf contains a single midrib and is translucent.

* Cooperative investigations of the U. S. Department of Agriculture, Agricultural Research Service, Southern Region, Florida-Antilles Area, the Central and Southern Florida Flood Control District, the Florida Agricultural Experiment Station, Fort Lauderdale, Florida, and the U. S. Army, Office of the Chief of Engineers, Washington, D. C.

** Formerly, Location Leader, U. S. Department of Agriculture, Agricultural Research Service, Southern Region, Florida-Antilles Area, Fort Lauderdale, Florida, and Chief, Aquatic Plant Control Program, Office, Chief of Engineers, Washington, D. C., respectively.

From two to four flowers with 10-mm yellowish-white petals rise from a single spathe which may extend 20 mm above the water surface. The flowers are insect pollinated. In alien populations, the female flower is unknown. Seeds have been found, but they are uncommon. Floating plant fragments provide the major means of plant dispersal.

3. *Egeria* is a native to South America, but it has become widely distributed throughout the world because of its use as an aquarium plant. *Egeria* and *elodea* are closely related, obviously much more closely related than either is to any other genus. In *elodea* there are species with perfect flowers. These seem more primitive than do the species with dioecious flowers which are often markedly dimorphic.⁴⁻⁸

4. Infestations of *egeria* are reported in California, Florida, Oregon, Virginia, Louisiana, Alabama, and South Carolina. Under conditions prevailing in the southeastern United States, *egeria* has become established as the dominant submersed plant in several large lakes, ponds, and slow-flowing rivers. Outside of Florida, the optimum growth conditions in the Southeast occur from April to September. In the colder areas there is a "dying back" to the root crown during the winter months.

5. *Hydrilla* (*Hydrilla verticillata* Royle) is a submersed plant, rooted to the bottom, with long, branching stems. The stems may break loose and form floating mats. *Hydrilla* needs just a little light to grow and has been observed in water over 12 m deep. The lower leaves are opposite and small, whereas the median and upper leaves are in whorls of three and are somewhat larger. The leaves are usually about 2 mm wide and 11-13 mm long. The flowers arise singularly from the spathe and are found at or near the surface and near the growing tip. The entire flower is inconspicuous and measures no more than 4-5 mm across the tip of a threadlike pedicel. The staminate plants are rare; thus, seed formulation, if any, is poor. An underground propagule is formed. *Hydrilla* differs from the related Brazilian *elodea* in that *Hydrilla* has sharply toothed leaf margins, prominent red veins, and a distinctly scabrous or harsh touch. Brazilian *elodea* often has a smooth, unbroken leaf margin and green midveins. *Elodea* has a

distinctly smooth leaf surface texture. One of the best tests for hydrilla versus elodea is by touch. Hydrilla, when drawn through the hand, feels harsh, brittle, and scratchy, while elodea feels smooth.

6. Hydrilla is found in canals, ponds, and streams, particularly in calcareous sites. It is strictly a submersed plant and cannot withstand extensive drying. Large infestations of hydrilla are found in drainage and irrigation canals, freshwater ponds and lakes, and even in flowing or tidal streams. This plant is found throughout most of the world, including the United States. Since about 1959, Florida has been invaded by hydrilla and is replacing Brazilian elodea and southern naiad. A ban on shipment and transportation of hydrilla is now in effect in the state of Florida.⁴⁻⁸

Chemical Control of *Egeria Densa*

Laboratory experiments

7. Culturing techniques were similar to those described by Blackburn⁹ for submersed plants. Terminal cuttings 10 cm long were collected from egeria growing in outside growth pools. The basal 2- to 3-node portions of two cuttings were placed in sandy-organic peat soil in a 5-cm plastic pot. Two pots were placed in a glass jar containing 3680 ml of one-tenth strength Hoagland's No. 1 nutrient solution in distilled water. The top of the jar was covered with a sheet of thin transparent plastic to prevent evaporation. The jars were placed in a controlled environment room with 125 ft/sec* of light for 14 hr followed by 10 hr of darkness. Room temperature was $22 \pm 2^{\circ}\text{C}$. At the end of a 3-week growth period, herbicides were added to the jars. At the time of treatment, egeria cuttings were 20-22 cm. Jars with uniform amounts of plant material were selected, and the herbicides were applied according to a randomized complete block design.

8. The visual herbicidal effect was recorded 2, 4, and 6 weeks after treatment. A rating scale of 0-100 was used (0 = no effect, 100 = complete kill).

* A table of factors for converting U. S. customary units of measurements to metric (SI) units is presented on page 4.

Growth pool experiments

9. Egeria cuttings were planted in outdoor, circular, plastic pools. A soil mixture (50 percent peat and 50 percent sand) was uniformly spread over the 7.2-sq-m area of the pool bottom to a depth of 15 cm. Terminal cuttings about 15 cm long were placed with the basal 8- to 10-cm portion in the soil. The pools were filled with pond water to an average depth of 0.56 m. The plants at the time of treatment extended to the surface. Each pool was stocked with six bluegills, three largemouth bass, and three channel catfish before herbicidal treatment.

10. Six weeks after establishment, the pools were treated with herbicides. The herbicides were dissolved in water and applied evenly over the pool surface. Each treatment was replicated three times, and three untreated pools served as controls. Evaluations were made 2, 4, 8 and 12 weeks after treatment to determine herbicidal effectiveness. A rating scale of 0-100 was used (0 = no effect, 100 = complete kill).

Field experiments

11. Herbicides that showed outstanding herbicidal activity on egeria in laboratory and growth pool tests were further evaluated in field plots. Canals and lakes with dense infestations of egeria were selected in Florida and South Carolina as the experimental sites. Plant sizes varied according to the size of the weed infection in the canal or lake and the amount of herbicides made available by the supplier. All plants were replicated three times and contained a minimum of 0.8 surface hectare.

12. Liquid herbicide formulations were applied with a power sprayer mounted in an airboat. The spray tank was equipped with a mechanical agitator to insure uniform mixing of the herbicide. The herbicide was injected approximately 3 m from the lake or canal bottom at a pressure of 350 kg/sq cm from hoses held near the bottom by a specially designed lead-filled nozzle tip. The amount of herbicide to be applied in each plot was mixed with enough water to equal 16 kl/hectare.

13. Granular and pelleted formulations were applied with a

motor-driven centrifugal spreader mounted on the bow of an airboat. Care was taken to insure uniform coverage of each plot. The amount of material applied in each plot varied with the average depth and the desired concentration.

14. Evaluations of herbicidal effects of the various herbicides and formulations were made at monthly intervals until the plot had regrown. Evaluations were made by two divers using SCUBA equipment and swimming through the treated area. In the evaluation a rating scale of 0-100 was used (0 = no effect, 100 = complete topkill). Percentage of regrowth of the plants in the plot was also recorded at each evaluation.

Results and discussion

15. The amine salt of endothall was more effective in laboratory experiments on egeria than were the potassium and dihydroxy salts (Table C1). These data confirm the results of previous experiments conducted with the amine salt of endothall.³ The dihydroxy salt and the potassium salt of endothall gave equivalent control of egeria. The addition of copper to endothall increased the effectiveness of both herbicides.

16. Diquat applied alone and in combination with a copper amine complex was very effective on egeria. The combination of diquat and copper has also been very effective on other species of submersed weeds.^{5,10}

17. A combination of diquat and endothall has been reported to control egeria.⁹ Laboratory results indicated that there may be a small advantage for the combination at low rates (0.25 + 0.25 ppmw). Recent research has indicated that there is no advantage for copper in this combination. Water temperature at the time of application may be very important when applying diquat or the combination for control of egeria.

18. Diquat (0.5 ppmw) and diquat plus endothall (0.5 + 0.5 ppmw) applied in growth pools gave good control of egeria (Table C2). No significant advantage was found for the addition of endothall or copper to the diquat treatment.

19. The amine salt of endothall was very effective on egeria but was toxic to fish. The potassium and dihydroxy aluminum salts of

Table C1

Evaluation of Herbicides and Herbicidal Combinations on
Egeria densa in Laboratory Experiments*

Chemical	Rate ppmw	Percent Control at Indicated Number of Weeks After Treatment		
		2	4	6
Endothall (amine salt)	0.5	40	70	85
	1.0	85	100	100
	2.0	100	100	100
Endothall (potassium salt)	0.5	15	25	35
	1.0	30	50	55
	2.0	50	65	78
Endothall (dihydroxy aluminum salt)	0.5	20	20	40
	1.0	20	35	50
	2.0	30	70	75
Endothall + copper (complex)	0.5 + 0.5	45	60	60
	0.5 + 1.0	53	75	78
	1.0 + 1.0	60	85	93
	2.0 + 0.5	75	98	100
Endothall + diquat	0.25 + 0.25	70	85	95
	0.25 + 0.5	93	100	100
	0.5 + 0.25	95	100	100
	0.5 + 0.5	100	100	100
Diquat	0.25	45	70	87
	0.5	70	100	100
	1.0	85	100	100
Diquat + copper (complex)	0.25 + 0.25	60	85	96
	0.25 + 0.5	70	90	98
	0.25 + 1.0	85	100	100
	0.5 + 0.25	80	100	100
	0.5 + 0.5	85	100	100
	0.5 + 1.0	93	100	100
Copper (complex)	0.5	25	40	55
	1.0	40	55	68
	2.0	65	93	97

* Each treatment replicated six times.

Table C2

Evaluation of Selected Herbicides and Herbicidal Combinations
on *Egeria densa* in Outside Growth Pool Experiments*

Chemical	Rate ppmw	Percent Control at Indicated Number of Weeks After Treatment				Percent Fish Toxicity
		2	4	8	12	
Diquat	0.5	75	93	95	93	0
Endothall (amine salt)	2.0	90	98	100	93	100
Endothall (potas- sium salt)	2.0	45	55	45	43	0
Endothall (dihy- droxy aluminum salt)	2.0	40	55	50	35	0
Endothall + diquat	0.5 + 0.5	87	98	100	100	0
Endothall + copper	2.0 + 0.5	75	93	90	83	0
Diquat + copper	0.5 + 0.5	93	100	100	100	0
Copper	2.0	65	50	32	10	35

* Each treatment replicated three times.

endothall did not harm fish but did not control the egeria. The toxicity of the amine salt of endothall to fish has been reported previously.⁵ The combination of copper and endothall increased the effectiveness of both herbicides.

20. Copper applied at the rate of 2 ppmw gave partial control of egeria but was also moderately toxic to fish. Regrowth was more rapid in the copper-treated pools than in the pools treated with other chemicals.

21. In the field trials, applications of 0.25 ppmw of diquat resulted in partial control of egeria, but excellent control was obtained when 0.25 ppmw of a copper complex was added to the treatment (Table C3). The phytotoxicity was greater when these two herbicides were combined than when either was applied alone. The apparent enhancement of activity is related to an increased uptake of both herbicides in the plant.⁵

Table C3
Evaluation of Several Herbicides and Herbicidal Combinations
On *Egeria densa* in Field Experiments*

Chemical	Rate ppmw	Percent Control at Indicated Number of Weeks After Treatment			
		4	8	12	16
Endothall (amine salt)	1.0	80	93	65	33
Endothall (TD-1874)	1.0	55	75	55	30
Endothall (amine salt, controlled-release)	1.0	70	95	85	70
Endothall (potassium salt)	2.0	25	40	50	25
Endothall (dihydroxy aluminum salt)	2.0	20	35	25	15
Endothall + copper	1.0 + 0.5	35	55	45	10
Diquat + endothall	0.25 + 0.25	50	80	80	75
Diquat + copper	0.25 + 0.25	85	90	98	97
Diquat	0.25	55	67	73	65
Check	0	5	13	10	3

* Each treatment replicated three times.

22. The amine salt of endothall was more effective than were the other salts of endothall. Endothall (TD-1874), which is closely related to the amine salt formulation, was more effective than were the dihydroxy aluminum and potassium salts. The controlled-release formulation of the amine salt was more effective and less toxic to fish than was the regular formulation. No fish toxicity was noted in the plants treated with the controlled-release formulation.

Chemical Control of Hydrilla

Growth pool studies

23. Herbicides that show promise in laboratory evaluations many times are not effective when evaluated in the natural environment.

The complexity and cost of initiating a field evaluation program on large numbers of experimental herbicides make it necessary to develop a simple technique of secondary evaluation.

24. During the past 5 years, the secondary evaluation of herbicides at this station has been done in small plastic growth pools. These evaluations provide valuable information on a new experimental herbicide in a simulated natural environment. The experiments are used to obtain information on (a) residue in soil, water, and plants, (b) toxicity to fish and fish food organisms, and (c) toxicity to a number of different plants. The major objective of these evaluations is to eliminate herbicides that are extremely toxic to the aquatic environment and those that are affected by natural environmental factors.¹⁰⁻¹²

Materials and methods

25. Submersed aquatic plants are planted in outdoor, circular, plastic pools. The plants used in the experiment were southern naiad (*Najas guadalupensis*) and hydrilla (*Hydrilla verticillata*). A soil mixture (50 percent peat and 50 percent sand) was uniformly spread over the pool bottom to a depth of 15 cm. Terminal cuttings about 20 cm long were placed with the basal 8- to 10-cm portion in the soil. The pools were planted with equal quantities of the three submersed aquatic plants. Pond water was used to fill the pools to an average depth of 0.56 m and then fish were placed in each pool. The plants at the time of herbicidal treatment extended to the surface.

26. The herbicides were applied to the pools at various concentrations. Liquid herbicides were dissolved in water prior to being uniformly distributed over the pool surface. Granular and pellet formulations were broadcasted evenly over the pool surface. Each treatment was replicated three times, and three pools remained untreated to serve as controls.

27. Water, plant, and soil samples about which residue information was required were removed 3, 7, 14, 21, 28, and 35 days after treatment. After treatment fish toxicity was checked daily for 2 weeks. Herbicidal control of the various species was recorded at 1, 2, 4, 8, and 10 weeks after treatment.

Results and discussion

28. The results of the treatments with the various herbicides evaluated in pool tests are shown in Table C4. All of the herbicides evaluated in these tests had shown promise in laboratory evaluations. Several of the more promising herbicides were also found to be extremely toxic to fish.

29. The comparison of the various formulations of hydrothol illustrates the importance of formulation when developing an aquatic herbicide. The hydrothol pellet was more effective on aquatic plants and less toxic to fish than were the other formulations.

30. These tests showed that toxicity of both diquat and endothall to hydrilla and southern naiad is increased when copper is added. The encapsulation of diquat and copper sulfate reduced the herbicidal activity. It is believed that part of the diquat and copper is tied up in the soil instead of being released into the waters.

Operational Large-Scale Field Tests

Program development

31. Since its introduction in Florida in 1960, Hydrilla verticillata has spread into many water areas in the lower two-thirds of peninsular Florida. Because of its unusual reproduction characteristics (vegetative and fruit), this aquarium plant has been transformed into a problem of major proportions within the field of submersed aquatics.

32. Since the need to find a solution to the problem was urgent, advice was sought from the Agricultural Research Service, U. S. Department of Agriculture, and others. The Florida Game and Fresh Water Fish Commission joined the Corps of Engineers in preliminary planning of a field test of certain registered chemical herbicides on hydrilla. Subject to concurrence of responsible State and Federal authorities, including fish and wildlife, public health, and water pollution control agencies, the Chief of Engineers on 7 May 1969 agreed that the Corps would participate and share costs as a part of the ongoing aquatic

Table C4
Herbicidal Activity and Fish Toxicity of Selected Herbicides on Two Species
of Submersed Weeds in Outside Growth Tanks*

Chemical	Rate ppmw	Percent Control at Indicated Number of Weeks After Treatment										Percent Fish Toxicity
		Naiad					Hydrilla					
		1	2	4	8	10	1	2	4	8	10	
Hydrothol (slow-release pellets)	2.0	12	25	55	80	98	20	53	85	97	100	0
	4.0	23	48	77	95	100	25	70	98	100	100	25
Hydrothol (granular)	2.0	20	57	75	80	80	25	72	81	55	50	75
	4.0	35	65	93	98	95	40	85	93	97	98	100
Hydrothol (technical)	2.0	60	77	90	90	78	52	78	92	88	78	65
	4.0	75	85	97	98	90	70	78	97	100	100	100
Hydrothol (liquid formulation)	2.0	85	95	97	98	93	85	94	96	98	90	100
	4.0	95	100	100	100	98	98	100	100	94	85	100
Endothall (dipotassium salt)	2.0	15	48	63	90	95	27	48	77	86	78	0
	4.0	25	65	87	99	100	35	60	85	98	100	0
Diquat	0.5	70	78	100	100	100	13	53	60	80	82	0
	1.0	73	82	100	100	100	20	65	85	93	98	0
Diquat + CuSO ₄	0.5 + 0.5	70	83	100	100	100	38	72	100	100	100	0
	1.0 + 1.0	78	95	100	100	100	55	90	100	100	100	0
Diquat + CuSO ₄ (encapsulated)	0.5 + 0.5	50	90	99	100	100	7	7	60	62	73	0
	1.0 + 1.0	55	95	100	100	100	25	38	78	85	90	0
CuSO ₄ (liquid)	1.0	38	58	63	52	25	27	57	48	37	25	0
CuSO ₄ (encapsulated)	1.0	10	25	48	40	35	0	10	28	35	30	0

* Each value is an average of three replications.

weed control operations in Florida.

33. Since the Navy, under the supervision of Agricultural Research Service and U. S. Department of Agriculture personnel, had been successful in using diquat and copper to treat hydrilla in Naval base lakes in Orlando during July-August 1968, these chemicals were selected for use in this test. The rate proposed was the same as that used previously, or 1 ppmw diquat and copper sulfate at 1 ppmw copper. However, prior to purchase of the herbicides, it was decided to divide the test area in half and use CUTRINE in Test Area No. 1 in lieu of copper sulfate. The rate of copper in the CUTRINE mix was 0.14 ppmw.

Application of herbicides

34. The herbicides were premixed in the desired ratio in a 2000-ℓ constant agitation tank parked near the center of the treatment area. The premixed herbicide was then pumped into 400-ℓ tanks mounted in each airboat. The herbicidal mixture in the airboat was agitated in that tank as it was pumped into the water by 60 ℓpm pumps.

35. The herbicides were mixed in a ratio of 9 to 1 (9 parts water to 1 part chemical). Test Area No. 1, containing 85.4 ha-m of water, was treated with 1 ppmw of diquat plus 0.14 ppmw of copper (CUTRINE). Test Area No. 2, containing 86.5 ha-m of water, was treated with 1 ppmw of diquat and an average of 0.86 ppmw of copper (COPPER SULFATE).

36. Three airboats were used in the herbicidal treatment. The airboat operated at an average speed of 8 km/hr. The herbicides were injected 1 m below the water surface from the stern of the airboat through three flexible drop-booms at a pressure of about 7 kg/sq cm. In depths of water in excess of 3 m, the injections were made 2 m below the surface. Treatment of Test Area No. 1 was accomplished on 19 August in about 14 hr time. The day was mostly sunny with threatening afternoon showers. Wind velocity was about 1.6 km/hr and the temperature ranged between 24 and 33°C. On 21 August diquat was used to treat Test Area No. 2, with instant copper sulfate on 75 percent of the area and coarser copper sulfate (snow) on the remaining 25 percent of the area. Test Area No. 2 was treated in about 11 hr. It rained several times during the application and the wind velocity was about 2 km/hr, with

the temperature ranging between 24 and 32°C. Details of the physical aspects are summarized in Table C5.

Efficacy evaluation

37. Evaluation stations were set up at eight locations in the treated area. These stations were permanently marked before the herbicidal treatments were applied. Divers using SCUBA equipment estimated the density of aquatic vegetation at each station before and at 3, 4, 14, 28, 48, 82, and 128 days after treatment. Two divers made independent evaluations at three locations in the station area. These three evaluations were averaged to determine the final evaluation of herbicidal control at each station.

Results and discussion

38. The effectiveness of the treatments is shown in Table C6. The combination of diquat and copper sulfate was more effective than was the diquat plus CUTRINE, and it gave a more rapid kill of hydrilla. Neither of the treatments gave 100 percent control of hydrilla.

39. The area treated with 1 ppmw diquat plus 0.8 ppmw copper (CuSO_4) showed pronounced herbicidal effects 3 days after application. The rapid drop of hydrilla is related to the higher concentration of copper. This area was scheduled to receive a 1 ppmw application of copper, but the water hardness prevented the use at this rate because of possible selective fish toxicity.

40. The application of 0.75 ppmw diquat plus 0.14 copper (CUTRINE) did not give effective control of hydrilla. Research that has now been completed shows that 0.75 ppmw diquat plus 0.28 copper (CUTRINE) will give control equivalent to that provided by the diquat plus copper sulfate.

Copper residue determinations

41. Copper in water and plant samples was determined with a Beckman DBG Spectrophotometer with an atomic absorption attachment. Water samples were cooled to just above freezing immediately after collection and kept in a refrigerator until sampled. Samples which contained less than 0.1 ppmw of copper were concentrated by heating 200 ml of the sample and evaporating it to 50 ml. Prior to heating, perchloric

Table C5
Data on Test Area, Chemicals Applied, and
Physical Aspects of Treatment

Plot No.	Test Area		Chemicals Applied			Physical Aspects	
	Depth m	Volume ha-m	Diquat ℓ	Cutrine kg	Copper kg	Water ha-cm/hr	Air Direction
A	4.8	6.9	6.9	12.3	-	- 514	WNW
B	4.0	1.2	1.2	2.3	-	S 514	
C	5.5	3.9	3.9	6.8	-	- 514	
D	8.3	7.1	7.1	13.2	-	- 514	
E	9.4	8.1	8.1	14.5	-	- 514	
F	4.2	3.1	3.1	5.5	-	- 514	
G	5.4	4.2	4.2	7.3	-	- 514	
H	9.0	7.7	7.7	14.1	-	- 441	N
I	10.1	8.7	8.7	15.9	-	- 441	
J	9.0	8.4	8.4	15.4	-	- 441	
K	8.7	8.4	8.4	15.4	-	- 441	
L	10.1	8.7	8.7	15.4	-	- 441	
M	11.0	4.8	4.8	12.7	-	- 587	NW
N	8.7	4.2	4.2	7.3	-	- 587	NW
Subtotals		85.4	85.4	158.0	-	- -	-
O	8.0	4.9	4.9	-	142	- 550	NW
P	8.0	4.4	4.4	-	128	- 587	NW
Q	11.0	4.8	4.8	-	189	- 587	
R	12.0	16.0	16.0	-	460	- 587	
S	8.9	12.3	12.3	-	354	- 587	
T	11.3	9.7	9.7	-	388	- 587	
U	10.0	8.6	8.6	-	343	- 441	WNW
V	8.0	8.4	8.4	-	240	- 441	
W	5.3	3.1	3.1	-	123	- 441	
X	7.8	6.9	6.9	-	272	- 441	WNW
Y	6.6	5.7	5.7	-	227	- 330	W
Z	5.0	1.8	1.8	-	72	- 330	W
Subtotals		86.5	86.5	-	2936	- -	-
Totals		171.9	171.9	158.0	2936	- -	-

Note: Area No. 1 treated with 1 ppmw of diquat plus 0.14 ppmw of copper (Cutrine).
Copper reduced to 0.86 ppmw except in plots O, P, R, S, and V.
Area No. 2 treated with 1 ppmw each of diquat and copper (copper sulfate).

Table C6
Comparison of Diquat Plus Copper Sulfate and Diquat Plus Copper
Complex (CUTRINE) on Hydrilla in Inglis Reservoir

Station* No.	Percent Herbicidal Control at Indicated Number of Days After Treatment						
	3	7	14	28	48	82	128
1	5**	10	25	45	65	78	50
2	0	15	40	55	75	80	45
3	3	15	40	50	70	75	40
4	5	30	35	40	70	70	40
5	10	30	60	75	85	89	65
6	15	40	55	70	90	95	70
7	15	55	65	85	95	95	80
8	10	45	60	80	90	93	80

* Stations 1-4 are in diquat plus CUTRINE treated area and
Stations 5-8 are in diquat plus copper sulfate.

** Average of three evaluations in the area.

acid was added to the aliquot at the rate of 0.5 ml/200 ml of water to keep the copper in the solution.

42. Plant samples were cooled to just above freezing immediately after collection and then dried at 60°C for at least 48 hr. The dried plant material was ground to 40 mesh with a Wiley Mill. The ground plant material was then digested with nitric and perchloric acids. Nitric acid was added at the rate of 10 ml/1.0 g of plant material and then allowed to set overnight. The plant material was heated until it was dissolved and the solution was clear, and then perchloric acid was added at the rate of 2.4 ml/1.0 g. The solution was heated until it turned clear and the copper in the solution determined. The results were expressed as micrograms of copper per grams of dried plant material (ppmw).

43. Known amounts of copper were added to the pretreatment water samples and plant samples to determine the recovery of copper after the samples were either concentrated or digested. Also, copper and diquat

were added to some water samples at the treatment site prior to treatment. Data are summarized in Tables C7 and C8.

Diquat residue determinations

44. Diquat in water samples was determined according to a colorimeter method.⁵ The limit of detection with this method is 0.01 ppmw diquat. Briefly, 10 ml of a 0.2 percent sodium dithionite in 0.3 N NaOH was added to 10 ml of a water sample. An intense green color was formed in the presence of diquat and immediately read at 390-370 mμ with a Beckman DBG Spectrophotometer with a recorder. Data are summarized in Table C9.

Results and discussions

45. The Student's t-test was used to compare means of copper in water samples, copper content of dried plant material, and diquat in water. The recovery of copper and diquat in water samples was 100 percent. Apparently no loss of these chemicals occurred during transit from the treatment area to the laboratory. The pretreatment water samples contained 0.006-0.003 ppmw of copper and the plant samples 6.3-2.3 ppmw of copper.

46. Water samples from Stations 3, 5, 7, and 8 contained concentrations greater than 0.1 ppmw 1 day after treatment. In general, more copper was in the top sample (0.3 m below the surface) than in the bottom sample (0.3 m above the hydrosol). The area treated with CSP plus diquat contained 0.129-0.102 ppmw of copper 1 day after treatment as compared with 0.035-0.036 ppmw for the CUTRINE-treated area. A rapid dissipation of copper from both areas occurred. The amount of copper in solution after 14 days was not significantly higher than the pretreatment levels.

47. Copper in the plant samples did not return to pretreatment levels within 28 days after treatment. Plants from the CUTRINE-treated areas contained from 14 to 5 ppmw of copper after 28 days as compared with 127 to 158 ppmw for plants in the CSP-treated area. In general, the top plant samples contained a higher concentration of copper than did the bottom samples for the 1-, 3-, and 7-day sampling periods.

48. An unequal distribution of diquat in the treated areas was

Table C7
Copper in Solution After Treatment of Inglis Reservoir

Station No.	Water Depth	Copper in Solution at Indicated Number of Days After Treatment, ppmw				
		0	1	3	7	14
1	T	0.004	0.021	0.014	0.012	0.007
	B	0.009	0.036	0.016	0.012	0.007
2	T	0.010	0.010	0.012	0.012	0.005
	B	0.006	0.024	0.014	0.012	0.007
3	T	0.009	0.125	0.024	0.007	0.005
	B	0.002	0.048	0.018	0.015	0.006
4	T	0.005	0.005	0.011	0.006	0.006
	B	0.002	0.018	0.010	0.006	0.005
5	T	0.009	0.060	0.027	0.012	0.008
	B	0.002	0.165	0.026	0.019	0.013
6	T	0.011	0.038	0.024	0.006	0.007
	B	0.005	0.034	0.026	0.007	0.010
7	T	0.004	0.350	0.080	0.012	0.008
	B	0.005	0.070	0.083	0.019	0.012
8	T	0.006	0.215	0.125	0.012	0.014
	B	0.001	0.100	0.025	0.007	0.011

Note: Samples for Stations 1-4 are from the area treated with diquat plus CUTRINE and Stations 5-8 from the diquat plus CSP.

Table C8
Copper Content of Hydrilla After Treatment of Inglis Reservoir

Station No.	Water Depth	Copper in Dry Plant Material at Indicated Number of Days After Treatment					
		0	1	3	7	14	28
1	T	4	252	75	109	32	23
	B	7	31	22	24	40	12
2	T	6	258	104	172	34	11
	B	10	17	14	18	18	9
3	T	4	260	550	43	92	15
	B	7	15	15	20	42	22
4	T	4	196	103	52	38	12
	B	3	16	35	11	17	9
5	T	7	1,870	1,470	2,000	218	--*
	B	7	38	90	79	51	36
6	T	7	126	214	75	50	11
	B	12	12	16	11	10	14
7	T	7	1,040	1,750	1,750	615	340
	B	6	43	112	1,480	3,240	410
8	T	6	2,460	1,230	990	550	49
	B	4	1,050	294	238	1,580	32

Note: Plant samples for Stations 1-4 are from the area treated with diquat plus CUTRINE and Stations 5-8 from the diquat plus CSP.

* No sample available.

Table C9
Colorimetric Determination for Diquat in Water Samples
After Treatment of Inglis Reservoir

Station No.	Water Depth	Diquat in Water at Indicated Number of Days After Treatment			
		1	3	7	14
1	T	0.18	0.10	---*	---*
	B	0.17	0.18	---*	---*
2	T	0.17	---*	0.11	---*
	B	0.15	---*	---*	---*
3	T	1.28	0.27	---*	---*
	B	0.45	0.14	---*	---*
4	T	0.18	0.14	0.11	---*
	B	0.13	0.15	---*	---*
5	T	1.74	0.28	---*	---*
	B	0.34	---*	---*	---*
6	T	0.09	0.04	---*	---*
	B	0.07	0.10	---*	---*
7	T	1.04	0.98	0.10	---*
	B	0.27	---*	0.17	---*
8	T	0.50	0.54	---*	---*
	B	0.64	0.12	---*	---*

Note: Samples from Stations 1-4 are from the area treated with diquat plus CUTRINE and Stations 5-8 from the diquat plus CSP.

* Not detectable.

determined 1 day after treatment, i.e., the top samples generally contained more of this herbicide than did the lower samples. Diquat in the water was below the detectable limit within 14 days after treatment; furthermore, diquat was detected in only three stations 7 days after treatment.

Benthic fauna

49. Samples of the bottom fauna were collected at Stations 4 and 7 with an Eckman dredge. Due to the difficulty of closing the dredge in an open spot on the bottom, only one 10-cm-sq sample was collected at each station. Station 4 was again sampled on 20 August 1 day after Area 1 was treated with diquat 1.0 ppmw mixed with CUTRINE 0.14 copper. No change in benthic fauna was observed as indicated in Table C10.

Table C10
Population of Benthic Fauna at Station 4

<u>Pretreatment, No./sq m</u>	<u>Posttreatment, No./sq m</u>
258 <u>Oligochaeta</u>	301 <u>Oligochaeta</u>
86 <u>Chaoborus</u> sp.	43 <u>Chaoborus</u> sp.
43 <u>Dicrotendipes</u> sp.	43 <u>Dicrotendipes</u> sp.
43 <u>Tanypus</u> sp.	43 <u>Tanypus</u> sp.

Water quality studies

50. Preapplication sampling was conducted by Jacksonville District personnel on 17 and 18 August 1970 for all stations. A field laboratory was set up using a Hach colorimeter for determining tannin and lignin (as tannic acid), nitrate nitrogen, ammonia nitrogen, and ortho phosphate. Also included were pH, alkalinity, dissolved oxygen, temperature and hardness tests. Samples were split and sent to the Florida Department of Air and Water Pollution Control Laboratory at Winter Haven, Florida, for analysis.

51. Postapplication samples were collected by Jacksonville District on 21 and 26 August 1970, 2 and 23 September 1970,

14 October 1970, and 19 November 1970. Data for 17 August, 23 September, and 14 October samplings are presented in Table C11.

52. As a result of plant decomposition, the ammonia nitrogen showed an increase immediately after it was sprayed. During the first 5 days, the ammonia nitrogen was oxidized to nitrate, thus lowering the concentration. After about 10 days the ammonia concentration stabilized.

53. Nitrate nitrogen dropped initially as a result of decomposition. In order for the decomposition process to start, nitrogen is needed. Furthermore, since the dissolved oxygen was low, the nitrate was reduced, yielding oxygen and causing a decrease in nitrate and an increase in ammonia. As the plants decayed, an increase in nitrate was detected for about one and a half months, after which the quality of water became stabilized.

54. Total hardness was not generally affected by the spraying operation. It naturally varies slightly over a period of time due to changes in flow.

55. Dissolved oxygen at the surface was not affected to any great extent. Bottom readings were the typically low August values and are related to decaying vegetation.

56. Alkalinity showed no appreciable fluctuation. The pH dropped sharply during the first 5 days after spraying. The drop can be attributed to the acidic nature of the chemicals involved.

57. The treatment of hydrilla in Inglis Reservoir was accomplished at a cost of \$115 per surface hectare, i.e., \$15 per surface hectare meter. Satisfactory control lasted about one season and re-treatment would be necessary for maintenance control.

Summary

58. During the past 10 years diquat and other herbicides have been researched extensively for control of egeria and hydrilla. Results of laboratory, growth pool, and field evaluations indicate that treatment is efficacious but must be repeated to maintain satisfactory control.

Table C11

Water Quality Data

Date 1970	Sta No.	Dissolved Oxygen		Alkalinity mg/l as CaCO ₃	Temperature °C		Hardness mg/l as Total	Nitrogen		Phosphate		Tannin and Lignin, mg/l
		Top	Bottom		Top	Bottom		mg/l NH ₄	mg/l NO ₃	mg/l ortho	pH	
8-17	1	11.7	0	92	28.0	27.0	120	0.54	0.03	0.75	7.5	1.59
	2	4.6	0	98	28.0	26.0	124	0.54	0.11	0.25	7.5	1.38
	3	4.4	0	86	28.0	27.0	118	0.35	0.02	0	7.7	1.05
	4	6.8	1	98	29.0	26.5	120	0.48	0.06	0.10	7.7	1.45
	5	8.5	0	70	29.0	27.0	115	0.21	0.01	0.20	7.7	0.75
	6	7.3	0	98	29.0	25.5	116	0.50	0.15	0.20	7.7	1.20
	7	--	0	78	28.0	26.5	117	0.33	0.01	0.30	7.7	1.05
	8	8.2	0	94	30.0	27.0	118	0.59	0.08	0.20	7.7	1.25
9-23	1	5.5	5.5	110	27.5	27.5	112	0.26	0.09	1.2	7.5	0.90
	2	8.4	7.4	112	27.5	27.0	114	0.28	0.13	0.2	7.5	1.10
	3	5.6	6.0	118	27.5	27.0	118	0.27	0.09	0.2	7.3	1.20
	4	7.6	5.8	134	28.0	27.0	120	0.21	0.08	1.1	7.5	1.00
	5	6.9	6.8	110	28.0	27.0	118	0.26	0.09	0.20	7.5	1.40
	6	6.6	7.8	110	27.5	27.0	116	0.28	0.09	0.20	7.4	0.90
	7	8.7	9.1	106	28.0	27.5	116	0.23	0.06	0.30	7.7	0.80
	8	7.0	7.7	104	28.0	27.5	118	0.29	0.14	0.20	7.4	1.10
10-14	1	5.7	--	126	26.0	25.5	118	0.15	0.03	0.50	7.4	0.80
	2	7.2	6.6	104	25.5	25.0	116	0.15	0.04	0	7.5	0.80
	3	5.2	4.0	112	25.0	25.0	120	0.20	0.11	0.20	7.3	0.80
	4	5.0	4.8	124	25.5	25.0	120	0.12	0.06	0	7.4	0.70
	5	4.9	5.3	122	26.0	25.0	120	0.29	0.05	0.50	7.3	0.80
	6	5.7	6.8	110	26.0	25.0	120	0.10	0.04	0.50	7.3	0.15
	7	6.3	7.3	116	27.0	25.5	118	0.19	0.05	0.30	7.4	1.10
	8	5.8	7.0	114	26.5	25.5	118	0.15	0.10	0.70	7.5	0.60

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APPENDIX D

GREENHOUSE STUDIES OF THE GROWTH AND
REPRODUCTION OF EGERIA DENSA

by

J. A. Foret, Principal Investigator
J. R. Barry, Associate Investigator
S. J. Langlinalis, Associate Investigator
S. L. Solymosy, Associate Investigator
D. P. Viator, Associate Investigator

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GREENHOUSE STUDIES OF THE GROWTH AND
REPRODUCTION OF *EGERIA Densa*

1. Laboratory and field observations of egeria from several locales indicate that this plant produces only male flowers under Louisiana conditions. At no time has it been observed to produce female flowers.

2. Vegetatively, it appears that only stem tips are able to reproduce Egeria densa. This would tend to limit the potential of spread by broken or cut plant pieces. The stem tips readily develop roots and resume growth while other portions of the plant stem remain green for a period of time and then decay.

Screening Studies of New Herbicides and New Herbicide
Formulations in the Greenhouse

3. Greenhouse growth containers utilizing polyethylene-lined buckets were started with several strands (about 12 in. long) of healthy egeria in each for the purpose of screening the chemicals for control.

4. Results obtained in screening tests with a number of test chemicals are shown in Table D1. The response of egeria to fenac is of interest. The formulation used was encapsulated in granules of polyvinylchloride (PVC), which releases the chemical slowly into the water. The results from this experiment suggest further investigation. Also of extreme interest was the response of egeria to Q-Dril at the lower concentration. Copper is combined in this formulation to enhance the activity of endothall. The influence of low dosage rates of Ethrel in combination with 2,4-D on egeria was noted with great interest. The lower rates of 2,4-D (approximately 4 lb/A) with 1.0 and 0.05 lb of Ethrel gave reasonable control and will be screened at lower rates of both.

5. It has previously been reported that diquat gives very effective control of egeria at minimal concentrations. To determine the concentrations of diquat needed for effective control, well established strands of egeria were removed from a growth tank and placed in

Table D1
Greenhouse Response of Egeria Strands to Various Chemicals*

Chemical	Rate	Rating**	
Fenac (30 percent acid in PVC)	300.0 ppmv	9.8	10.0
Fenac (30 percent acid in PVC)	6,000.0 ppmv	10.0	--
Niagara 10656	5.0 ppmv	10.0	--
Niagara 10637	5.0 ppmv	10.0	--
Niagara 10637	100.0 ppmv	0	--
Ethrel 1757	0.5 ppmv	0	--
Ethrel 1757	100.0 ppmv	0	
Ethrel 1758	0.5 ppmv	0.5	--
Ethrel 1758	100.0 ppmv	0	--
Q-Dril (20 percent endothall, 10 percent metallic copper)	200.0 ppmv	10.0	10.0
Q-Dril (20 percent endothall, 10 percent metallic copper)	6,000.0 ppmv	10.0	10.0
Endothall	100.0 ppmv	0	--
Endothall	2,000.0 ppmv	10.0	--
Hydost (10 percent endothall acid)	50.0 lb/A	--	10.0
	100.0 lb/A	--	10.0
Ethrel	45.5 ppmv	--	
+ 2,4-D PGBEE	1,816.0 ppmv	--	8.0
Ethrel	22.7 ppmv	--	7.0
+ 2,4-D PGBEE	1,758.0 ppmv	--	7.0
Ethrel	22.7 ppmv		--
+ 2,4-D PGBEE	3,632.0 ppmv	--	5.0
Ethrel	45.5 ppmv	--	5.0
+ 2,4-D PGBEE	1,816.0 ppmv	--	--

* Chemicals applied to water at concentrations shown, and plants allowed to remain in the treated water.

** Ratings in left column represent treatments initiated 16 March and rated 12 May 1971; ratings in right column represent treatments initiated 2 July and rated 25 August 1971; 0 denotes no control, 10 denotes complete control.

containers. Time exposure studies were conducted utilizing two rates of diquat, 0.5 and 5 ppm formulated material (active herbicide: 0.019 and 1.9 ppm, respectively), in an aqueous solution. Time exposures were 5 and 20 min and 3, 6, 12, and 48 hr. The strands were then immersed in 4000 cc of tap water. The treatments were then evaluated 7, 10, and 24 days after removal from the herbicide exposure. The results are shown in Table D2.

6. Based on the results from this experiment it appears logical to conclude that diquat injected or propeller-washed into the mat at a concentration as low as 0.05 ppm will be absorbed in lethal doses by the plant parts exposed to the chemical for 3 hr.

7. As indicated in Table D2, exposures to some chemicals for the duration of only 3 hr is sufficient to have them absorbed by egeria in lethal doses. In Tables D1 and D2 the entire plants of egeria were exposed to the herbicides. It seemed advisable, however, to determine if and how the chemical is translocated by the plant. This was of importance since it was observed that in experimental pools and in field treatments only the plants of egeria in the upper water layer or those plant parts in direct contact with the chemical were affected by it.

Table D2
Diquat Time Treatment

Exposure Time	Treatment Rating* for Indicated Amount of Diquat at Indicated Number of Days After Treatment					
	0.05 ppm			5 ppm		
	Days After Treatment			Days After Treatment		
	7	10	24	7	10	24
5 min	0	2.0	2.0	0	5.0	7.0
20 min	0	7.0	10.0	0	5.0	7.0
3 hr	0	7.0	10.0	0	9.0	10.0
6 hr	0	7.0	10.0	5.0	10.0	10.0
12 hr	0	7.5	10.0	7.5	10.0	10.0
48 hr	0	6.0	10.0	9.0	10.0	10.0

* 0 denotes no control; 10 denotes complete control.

8. It was therefore decided to expose only the tips and central portions of egeria to diquat for as long as 3 hr, after which time the whole plant was then placed in cylinders filled with tap water. A concentration of 5 ppm was used in the experiment. The results are presented in Table D3.

9. As indicated in Table D3, no translocation could be observed. The plants discolored and finally disintegrated only at the treated portions, growing and multiplying vigorously from the untreated sections. The work was expanded to include other chemicals included in Table D2.

10. Submersed aquatic plants are subject to vertical and horizontal water movement within the aquatic environment. The effectiveness of aquatic herbicides decreases with an increase in horizontal water movement and a decrease in vertical water movement. The vertical movement of water is fairly well restricted as the density of submersed vegetation increases. Therefore, tests have been concerned with minimum exposure times required for the effective chemical control of egeria.

Table D3
Diquat Translocation Test

<u>Date</u>	<u>Treatment or Observation</u>
7 July 1971	Applied to tip portion
16 July 1971	Tip portion rated 10.0
25 August 1971	Untreated portion resuming full growth
7 July 1971	Applied to central portion
16 July 1971	Central portion rated 10.0
25 August 1971	Untreated tip portion resuming full growth

11. Based on the results from the previously discussed experiments involving time exposure and plant part treatments, it may be

cautiously stated that egeria does not translocate all chemicals as efficiently as do many other plants. A possible explanation that could account for this is that one basic difference between egeria and many other submersed aquatics is that egeria is a monocotyledonous plant. The vascular system of monocots is contained within vascular bundles in the stem. These vascular bundles are usually isolated from one another in the stem by parenchyma tissue.

12. Anionic substances (nitrogen compounds, phenoxy-type herbicides, etc.) are generally transported through the phloem tissue in plants, while the cationic materials such as nutrient salts and the salts of many herbicides are transported in the xylem. From the plant-part treatments cited above, it is apparent that these tissues serve as a poor means of herbicidal movement within the egeria plant for two reasons, namely, the nature of the vascular system of monocots in general and particularly egeria, and the apparent presence of tissue and/or physiological barriers to the movement of herbicidal materials within the vascular system of this plant.

13. It seemed, therefore, that the only plausible approach to the problem would be to expose the plant in its total length to the herbicide in minimal lethal dosages, i.e., to suspend the chemical in the supporting column of water for at least 3 hr, a period which has been found sufficient for the chemical to be absorbed in a lethal dose. Within the time span of 3 hr little horizontal and/or vertical water movement would be anticipated, especially in the dense mats in which egeria grows.

14. The wettable powder formulations of most herbicidal materials are usually formulated by crushing or grinding an inert carrier or diluent to very fine particle size (100-500 mesh). There is generally a wide range of particle sizes within a given sample, some being so large as to require constant agitation in the spray tank to insure uniform dosage. The varying particle sizes of wettable powders provide a ready-made means of distributing the chemical in water columns partially filled with vegetation such as egeria. Distribution is made more efficient by the presence of various natural and collected layers of

gelatinous materials on leaf surfaces to which the particles would adhere. The very finest particles will remain in suspension for varying periods of time due to Brownian movement.

15. It was therefore decided to test the validity of this hypothetical statement. Healthy strands of egeria were placed in 38-cm-deep cylinders filled with clear water, and various herbicides in wettable powder form were added in a watery suspension to the supporting water. The first experiments verified the hypothesis regarding the behavior of wettable powders in an aquatic environment.

16. It was noted that the cylinder to which dichlobenil had been added had a cloudy appearance, indicating some material was still in suspension after 48 hr.

17. Wettable powder formulations of several herbicides available in the laboratory were applied at rates varying from 5 to 50 lb per acre.

18. Requests were made in August 1971 of several manufacturers of herbicides to formulate wettable powders of diquat, 2,4-D (several formulations), and silvex. Laboratory trials are planned for early spring- and summer-simulated conditions. It is possible that the wettable powders may be more efficient at the time that egeria is commencing spring growth and while still deeply submerged.

19. Re-evaluation of several previously screened chemicals and combinations of chemicals were accomplished during 1971-72 in the greenhouse. In addition, new chemicals and different combinations of chemicals were also evaluated. Treatments tested and the results obtained are shown in Tables D4-D8.

20. Several polyethylene-encapsulated formulations of 2,4-D were included in the laboratory studies in 1971-72. These slow release formulations are designed to release 2,4-D into the aqua-system over a prolonged period. In addition, several other treatments were included in the experiment for the purpose of comparison. The treatments, rates, and ratings obtained in this experiment are shown in Table D4. Of the treatments tested, Pencap 48-1 and GD-26 proved to be the most effective.

Table D4
Greenhouse Screening Tests for Fall and Winter 1971-72

Treatment	Rate, lb ai/A	Rating*
2,4-D(DEA)** + Molasses	2 1 gal/A	5.0
Ethephon† + 2,4-D(DEA)	1 1	6.0
Q-Drill††	5	7.0
Hydout‡	5.0	5.0
Fenac acid	5	8.0
Pencap encapsulated formulations of 2,4-D‡‡		
48-1	3.5	10.0
53-1	5.5	7.5
45-1	3.5	0.0
50-1	3.0	8.0
44-1	3.0	4.5
GD-26§	3.2	9.5

- * 0 denotes no control; 10 denotes complete control.
 ** Diethenol amine formulation.
 † (2-Chloroethyl) phosphonic acid.
 †† 20 percent endothall, 10 percent metallic copper.
 ‡ 10 percent endothall acid.
 ‡‡ Iso-octyl ester supplied by Pennwalt Corporation.
 § Experimental herbicide by Smith-Corona-Marchand.

Table D5
Wettable Powders Used in Greenhouse Screening Tests
Winter 1972*

<u>Treatment</u>	<u>Rate, lb ai/A</u>	<u>Rating**</u>
Check	--	1.5
Fenac acid	1.0	2.5
	5.0	6.0
	10.0	10.0
Na salt of fenac	1.0	0.5
	5.0	2.5
	10.0	8.5
2,4-D(87 percent acid)	5.0	5.0
	10.0	9.0
2,4-D(DMA salt)	5.0	2.0
	10.0	3.5
2,4-D(butoxyethyl ester)	5.0	2.5
	10.0	3.0
2,4-D(ammonium salt)	5.0	4.0
	10.0	8.0
Ethephon†	5.0	9.5
	10.0	9.5

- * Three replications per treatment rated 6 weeks after application.
 ** 0 denotes no control; 10 denotes complete control.
 † (2-Chloroethyl) phosphonic acid.

Table D6
Greenhouse Screening Tests, Spring 1972

<u>Treatment No.</u>	<u>Chemical</u>	<u>Rate, lb ai/A</u>	<u>Rating*</u>
1	Paraquat WP	5	10.0
2	NB 7-191-5**	5	9.4-10.0†
3	H-47** NB 7-191-2	5	7.4-10.0†
4	H-191** NB 7-191-3	5	8.3-10.0†
5	TD 16159** NB 7-191-4	5	8.0-10.0†
6	TD 512** NB 7-191-1	5	5.0-10.0†
7	TD 1929** NB 7-180-5	5	7.0-10.0†
8	TD 1932** NB 7-182-6	5	4.0-10.0†
9	TD 490** NB 7-143-2	5	8.3-10.0†
10	TD 1874** NB 7-180-4	5	7.4-10.0†
11	1139**	5	5.4-10.0†
12	Check	--	1.0-1.5

- * 0 denotes no control; 10 denotes complete control.
 ** Experimental formulation.
 † Retreated after 30 days.

Table D7
Greenhouse Screening Tests with Wettable Powder
Combinations of Herbicides on Egeria

<u>Treatment No.</u>	<u>Ethephon lb ai/A</u>	<u>2,4-D lb ai/A</u>	<u>Rating*</u>
1	0.05**	8.0†	8.5
2	0.10	8.0†	8.5
3	0.05	4.0†	4.7
4	0.10	4.0†	5.4
5	0.05	8.0††	5.3
6	0.10	8.0††	6.0
7	0.05	4.0††	6.3
8	0.10	4.0††	5.5
9	0.05	8.0‡	9.0
10	0.10	8.0‡	9.0
11	0.05	4.0‡	8.0
12	0.10	4.0‡	7.3
13	0.05	8.0‡‡	8.3
14	0.10	8.0‡‡	9.0
15	0.05	4.0‡‡	8.0
16	0.10	4.0‡‡	9.0
17	0.05	8.0§	9.0
18	0.10	8.0§	8.6
19	0.05	4.0§	8.5
20	0.10	4.0§	9.0
21	0.05	8.0§§	8.5
22	0.10	8.0§§	8.4
23	0.05	4.0§§	8.5
24	0.10	4.0§§	8.0
25	Check	Check	1.0

* Rating made 4 weeks after treatment and reported as the mean of three replications--0 denotes no control, 10 denotes complete control.

** (2-chloroethyl) phosphonic acid, 2 percent wettable powder (used for all treatments).

† Propyleneglycol butyl ether ester.

†† Diethanol amine.

‡ Dimethyl amine salt, 25 percent wettable powder.

‡‡ 2,4-D acid, 97 percent wettable powder.

§ Ammonium salt, 25 percent wettable powder.

§§ Butoxyethyl ester, 25 percent wettable powder.

Table D8
Greenhouse Screening Tests with Wettable Powder Mixtures

<u>Treatment</u>	<u>Rate lb ai/A</u>	<u>Rating*</u>
TD 16159	5.0	10.0
NB 7-191-A**		
TD 1874	5.0	10.0
NB 7-180-4**		
TD 1929	5.0	10.0
NB 7-180-5		
TD 1932	5.0	10.0
NB 7-182-6**		
TD 512	5.0	10.0
NB 7-191-1**		
Check		0.2

* 30 days after treatment; 0 denotes no control, 10 denotes complete control.

** Wettable powder mixtures.

21. The wettable powder herbicide formulations listed in Table D5 were introduced into greenhouse screening tests in January 1972. As noted in an earlier report, wettable powders tend to settle more uniformly over the foliage and provide good coverage of the submersed plants. Ratings for control from this study are presented in Table D4. The highest rates of fenac acid, fenac sodium salt, 2,4-D acid, 2,4-D ammonium salt, and ethephon resulted in good control when tested in 4-ℓ beakers.

22. Table D6 shows the chemicals, rates, and results obtained in laboratory screening trials conducted in 4-ℓ beakers during the spring of 1972. Paraquat was formulated into a wettable powder in the laboratory by mixing the liquid paraquat formulation with a wettable powder and air drying the mixture. Results in Table D6 indicate the

diatomaceous earth in the formulation did not alter the effectiveness of paraquat. This formulation resulted in complete kill after the first treatment, while retreatment was required for all other treatments in order to achieve this level of control.

23. In Table D7 are the results obtained with wettable powder combinations of ethephon and 2,4-D at different rates. This study indicates a greater interaction and enhancement of herbicidal activity in the ethephon-2,4-D combinations when the wettable powder formulations were used. The wettable powder of 2,4-D acid (treatments 13-16) indicated as high an activity as did any of the other 2,4-D formulations in combination with ethephon. However, in treatments 15 and 16, 19 and 20, and 23 and 24, the lower rate of 2,4-D was as effective as the higher rate with either rate of ethephon.

24. Greenhouse screening tests during the summer of 1972 included some of the same experimental formulations listed in Table D6, with the exception that the materials were mixed with a wettable powder of diatomaceous earth and applied in this manner to obtain foliar coverage of egeria. The results obtained from this experiment are shown in Table D8.

25. In all cases, mixing the encapsulated chemicals with a wettable powder to concentrate the herbicide on the leaves and stems of the plant resulted in complete kill of egeria when rated 30 days after treatment. In earlier tests (Table D7), a retreatment was necessary to obtain this degree of control.

26. A second series of screening tests were conducted in which the pH of the water was adjusted to evaluate the effects of 2,4-D on egeria growing in acidified water. Hydrochloric and sulfuric acids were used to lower the pH from 8.4 (tap water) to 5.0. The results obtained from this experiment are presented in Table D9. Lowering the pH with sulfuric acid alone resulted in control after 3 days in the greenhouse without the addition of 2,4-D. Egeria was effectively controlled by hydrochloric acid treatment in 10 days without the addition of 2,4-D. It was therefore concluded that acidifying the water would result in fast control of egeria without the addition of 2,4-D. Further

Table D9
Greenhouse Screening Tests with 2,4-D Amine
and pH Adjustment of Water

<u>Treatment</u>	<u>Rate lb ai/A</u>	<u>Rating*</u>
Check (pH 8.4)	--	2.0
pH 5.0 (HCl)	--	10.0 (10 days after treatment)
pH 5.0 (HCl) + 2,4-D amine	5.0	10.0 (3 days after treatment)
ph 5.0 (H ₂ SO ₄)	--	10.0 (3 days after treatment)
pH 5.0 (H ₂ SO ₄) + 2,4-D amine	5.0	10.0 (3 days after treatment)

* 0 denotes no control; 10 denotes complete control.

evaluation of these treatments will be made in outdoor pools to determine if adjusting the pH would be feasible in larger areas.

27. Extremely cloudy and cold weather negated greenhouse studies attempted during the fall of 1972.

28. In February screening of chemicals began with experimental herbicides supplied by Shell Development Corp. (SD) and Dupont (DPX). Information was received suggesting the effectiveness of dichlobenil in combination with copper for the control of egeria.

29. Table D10 lists the compounds screened in containers in the greenhouse. As in previous tests, four strands of Egeria densa were established in each container with three replications of each treatment. All chemicals used in these tests were formulated as wettable powders.

30. DPX 1840 at 0.25 lb ai/A of surface area resulted in acceptable control and when combined with 2 lb of fenac gave complete control of Egeria densa (Table D10). Control of egeria was almost as good when DPX was combined with 2,4-D amine. The lower rates in all screening

Table D10
Greenhouse Screening Tests for Control of
Egeria densa with DPX 1840*

<u>Treatment</u>	<u>Rate, lb ai/A</u>	<u>Date Applied</u>	<u>Rating**</u>
1-Check		2/15	1.5
2-DPX 1840	0.25	2/15	9.0
3-DPX 1840	2.00	2/15	9.0
4-DPX 1840	0.25	2/15	10.0
+ Fenac	2.00		
5-DPX 1840	0.25	2/15	10.0
+ Fenac	8.00		
6-DPX 1840	2.00	2/15	8.0
+ Fenac	2.00		
7-DPX 1840	2.00	2/15	8.3
+ Fenac	8.00		
8-DPX 1840	0.25	2/15	9.4
+ 2,4-D (DMA)	2.00		
9-DPX 1840	0.25	2/15	10.0
+ 2,4-D (DMA)	8.00		
10-DPX 1840	2.00	2/15	8.0
+ 2,4-D (DMA)	2.00		
11-DPX 1840	2.00	2/15	8.7
+ 2,4-D (DMA)	8.00		

* DuPont experimental herbicide.

** Ratings made 15 March 1973; 0 denotes no control, 10 denotes complete control.

tests appeared to be most effective.

31. SD 16389 was also most effective at the lower rates in controlling egeria (Table D11). Additions of a small quantity of fertilizer did not significantly enhance the herbicidal activity.

32. Dichlobenil in combination with organic copper (K-lox) at 0.5 ppm each shows promise as a combination treatment (Table D12).

Table D11
Greenhouse Screening Tests for Control
of Egeria with SD16389*

<u>Treatment</u>	<u>Rate</u>	<u>Date Applied</u>	<u>Rating**</u>
1-Check		3/28	1.0
2-SD16389	0.1 ppm	3/28	9.0
3-SD16389	0.3 ppm	3/28	5.3
4-SD16389	0.5 ppm	3/28	10.0
5-SD16389	0.7 ppm	3/28	9.7
6-SD16389	1.0 ppm	3/28	6.7
7-SD16389	0.1 ppm	3/28	9.0
+ Fertilizer (8-8-8)	0.4 g/ft ²		
8-SD16389	0.3 ppm	3/28	7.0
+ Fertilizer (8-8-8)	0.4 g/ft ²		
9-SD16389	0.7 ppm	3/28	3.0
+ Fertilizer (8-8-8)	0.4 g/ft ²		
10-SD16389	1.0 ppm	3/28	2.0
+ Fertilizer (8-8-8)	0.4 g/ft ²		
11-Fertilizer (8-8-8)	0.4 g/ft ²	3/28	1.0

* Shell experimental herbicide.

** Ratings made 27 April 1973; 0 denotes no control, 10 denotes complete control.

Table D12
Greenhouse Screening Tests for Control
of Egeria with Dichlobenil

<u>Treatment</u>	<u>Rate, ppm</u>	<u>Date Applied</u>	<u>Rating*</u>
1-Check		4/3	0.5
2-dichlobenil	0.25	4/3	6.0
+ copper	0.5		
3-dichlobenil	0.5	4/3	9.0
+ copper	0.5		
4-dichlobenil	1.0	4/3	8.3
+ copper	0.5		

* Ratings made 2 May 1973; 0 denotes no control, 10 denotes complete control.

Outdoor Pool Studies

33. Several herbicide treatments which had shown significant herbicidal activity on Egeria densa in laboratory screening studies were tested in outdoor pools during the spring and early summer of 1972. The study included 18 chemical treatments and a nontreated check with two replications per treatment arranged in a completely randomized design. The plot size was 25 sq ft, with each plot containing 1 ft of water over 2 in. of clay soil.

34. On 15 March, 50 strands of egeria were planted in each plot. Chemical treatments were applied on 5 May when the egeria had become well established in the plots. Ratings were made on 13 June without draining the pools and again on 28 June after the pools were drained. The results of the ratings are shown in Table D13.

35. Results of the study indicated the most promising treatments and rates were TD-1929 (4 ppm), GD-26 (6 and 8 ppm), H-47 (4 ppm), diquat (1/4 and 1/2 ppm) plus copper ion (2 ppm), and fenac (2 and 4 ppm). Diquat (1/4 and 1/2 ppm) applied without copper ion, 2,4-D

Table D13
Effects of Herbicide Treatments Upon Weed Control Ratings
in Egeria Densa Grown in Plastic Lined Pools

Treatments	Rate, ppm	Mean Ratings*	
		6-13-72**	6-28-73†
TD-1929	4	9.0	8.0
GD-26	8	8.7	9.0
H-47	4	8.0	8.0
Diquat + Cu	1/2 + 2	7.7	9.0
Diquat + Cu	1/4 + 2	6.5	5.5
GD-26	4	6.2	3.5
Amchem 71-A5 (fenac)	4	6.2	8.5
Amchem 71-A5 (fenac)	2	6.0	7.0
GD-26	6	6.0	8.0
GD-26	2	4.7	2.0
Amchem LFN 472 (2,4-D)	4	4.5	2.0
Diquat	1/4	4.0	1.5
Amchem LFA 472 (2,4-D)	3	3.7	1.5
Amchem LFN (2,4-D) + sulphur	3 + 8	3.5	3.5
Amchem LFN 472 (2,4-D) + sulphur	3 + 4	2.7	1.5
Diquat	1/2	2.7	0.0
Check	0	2.5	2.0
Amchem 68-292 (ethephon wettable powder)	4	1.5	1.0
Amchem 68-292 (ethephon wettable powder)	2	0.5	0.5

* Ratings where 0 denotes maximum vigor and 10 denotes complete kill.

** Means followed by a common bar do not differ significantly at the 5 percent level of probability.

† Ratings of drained pools.

(3 ppm) and ethephon (2 and 4 ppm) were not statistically different from the check treatment.

36. One pool study was conducted during the summer of 1973 to evaluate several herbicides. The herbicides evaluated included

commercial herbicides as well as experimental materials that had given significant control in greenhouse experiments during the past year.

37. Fourteen herbicide treatments and a check were arranged in a completely randomized design with two replications per treatment. The rate of each herbicide was calculated based upon pounds of active ingredient per acre of surface area. Herbicidal treatments in a volume of 2 gal of water were applied manually to each plot.

38. The treatments were applied on 15 June and visual ratings on control were made on 12 and 27 July. In addition, fresh weights of each treatment were determined on 2 August.

39. Statistical analyses of the data included the analysis of variance for determination of significant F values. Significant mean differences at the 5 percent level of probability were determined with the Duncan Multiple Range Test.

40. The analysis of variance for the visual control ratings made on 12 and 27 July are presented in Tables D14 and D15, respectively.

Table D14

Analysis of Variance Table for 12 July Visual Rating

<u>Sources of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>
Among treatment	14	213.7	15.3	6.0
Within treatment	15	39.0	2.6	
Total	29	252.7		

Table D15

Analysis of Variance Table for 27 July Visual Rating

<u>Sources of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>
Among treatment	14	294.5	21.1	14.1
Within treatment	15	22.8	1.5	
Total	29	317.3		

41. The F values for among treatment component for both dates of evaluation were highly significant. Therefore, significant mean differences were determined utilizing the Duncan Multiple Range Test. The herbicidal treatments and ratings for 12 and 27 July are shown in Tables D16 and D17, respectively.

Table D16
Visual Control Rating on 12 July

Herbicide and lb ai/A	Mean*
Diquat (1.35)	10.0
Diquat (1.35) + K-lox** (1.35)	10.0
SD 16389† (0.27) + K-lox (1.35)	8.3
SD 16389 (1.35)	7.8
K-lox (1.35)	7.5
SD 16389 (0.27)	7.0
DPX 1840†† (0.25) + K-lox (1.35)	7.0
Dichlobenil (1.35) + K-lox (1.35)	5.5
DPX 1840 (1.0)	4.3
DPX 1840 (2.0)	3.5
Fenac (10.0)	3.3
Dichlobenil (1.35)	2.8
Fenac (5.0)	2.0
Check	0.3
DPX 1840 (0.25)	0.0

* 0 denotes no control, 10 denotes complete control. All means which are followed by a bar in common do not differ significantly at the 5 percent level of probability.

** Copper hydroxide triethanolamine complex.

† Shell experimental herbicide.

†† DuPont experimental herbicide.

Table 17
Visual Control Rating on 27 July

<u>Herbicide and lb ai/A</u>	<u>Mean*</u>
Diquat (1.35)	10.0
Diquat (1.35) + K-lox (1.35)	10.0
SD 16389 (1.35)	9.5
SD 16389 (0.27)	9.3
SD 16389 (0.27) + K-lox (1.35)	9.0
K-Lox (1.35)	7.7
DPX 1840 (0.25) + K-lox (1.35)	6.5
Fenac (10.0)	6.3
Dichlobenil (1.35)	5.0
Dichlobenil (1.35) + K-lox (1.35)	4.5
DPX 1840 (2.0)	4.0
DPX 1840 (1.0)	3.8
Fenac (5.0)	3.3
DPX 1840 (0.25)	0.5
Check	0.5

* 0 denotes no control, 10 denotes complete control. All means which are followed by a bar in common do not differ significantly at the 5 percent level of probability.

42. The data obtained from the two dates of evaluation indicated no significant interaction between dates and herbicide. The treatments which were significantly superior were the following: diquat (1.35 lb ai/A), diquat (1.35 lb ai/A) + K-lox (1.35 lb ai/A), SD 16389 (0.27 lb ai/A) + K-lox (1.35 lb ai/A), SD 16389 (1.35 lb ai/A), K-lox (1.35 lb ai/A), SD 16389 (0.27 lb ai/A) and DPX 1840 (0.25 lb ai/A) + K-lox (1.35 lb ai/A).

43. In addition to visually rating the treatments for control of Egeria densa, fresh weights were obtained on 2 August. The data obtained are shown in Table D18.

44. Although there were no significant differences among

Table D18
Fresh Weights of Treatments

Herbicide and lb ai/A	Mean, g*
SD 16389 (0.27)	0.0
Diquat (1.35)	0.0
Diquat (1.35) + K-lox (1.35)	10.0
SD 16389 (0.27) + K-lox (1.35)	10.2
SD 16389 (1.35)	15.0
K-lox (1.35)	340.0
DPX 1840 (0.25) + K-lox (1.35)	536.8
Dichlobenil (1.35) + K-lox (1.35)	692.5
Dichlobenil (1.35)	881.8
DPX 1840 (1.0)	1675.5
Fenac (10.0)	2388.5
Fenac (5.0)	2706.5
Check	3116.0
DPX 1840 (0.25)	3274.0
DPX 1840 (2.0)	3477.5

* 0 denotes no control, 10 denotes complete weed kill. All means which are followed by a bar in common do not differ significantly at the 5 percent level of probability.

treatments 1-9, SD 16389 and diquat had numerically the lowest fresh weights.

45. A measure of the fresh weight remaining at the termination of the experiment is considered a more reliable estimate of control than is visual observation. However, under field conditions fresh weight data could not be practically obtained.

46. In order to determine the reliability of visual ratings, the association between the visual rating made on 27 July and the fresh weight data was determined by the calculation of the correlation coefficient.

47. A correlation coefficient of 0.44 was obtained. The r value

was positive and moderate in strength although not statistically significant. This is interpreted to mean that those treatments that gave the best control when evaluation was based on fresh weights also tended to be the ones that were the most effective based on visual ratings and vice versa. Although the correlation coefficient was not statistically significant, this could have been caused by a low number of degrees of freedom in the experiment or by the nonlinearity association between the two variables.

48. Close examination of the data showed that the seven most effective treatments based on visual observations were also the same treatments that had the lowest fresh weights, although the ranking of these seven treatments was not identical for both systems of treatment evaluation. This is interpreted to mean that visual rating of pools is reliable. However, the same precision would not be expected under field conditions since it is generally not possible to view through the entire water column in a lake or river unless the plots are examined by SCUBA divers.

Small-Scale Field Testing

49. In July 1971, suitable field sites were located for small plot trials. These experiments were conducted in a shallow lake (6-8 ft deep), with a dense stand of egeria along with lesser infestations of Ceratophyllum and Utricularia.

50. Plots of 4000-sq-ft surface area (200 by 20 ft) were oriented so that the 200-ft length of each was parallel to the prevailing wind to minimize horizontal drift of the chemicals applied. Each treatment was replicated three times.

51. Chemicals were mixed into a water volume equivalent to 300 gpa and injected into the mats of egeria by holding the spray boom just above the water surface. A straight-jet nozzle was used to inject the solution about 24 in. deep at 100 psi.

52. Table D19 shows the results obtained from these preliminary trials. The rating given is the mean of the three replicates scored

Table D19
The Effects of Several Herbicides on Control of Egeria
Under Field Conditions in July 1971

Chemical	Rate	Date Applied	Rating*	
			Surface**	Subsurface†
Diquat	0.5 ppm (top acre-foot)	7/6	9.0	6.0
Diquat	0.5 ppm (top acre-foot)	7/14	9.4	6.3
2,4-D (PGBEE) +	2 lb ai (surface acre)	7/6	5.6	3.0
Molasses	1 gal (surface acre)			
2,4-D (PGBEE) +	2 lb ai (surface acre)	7/14	6.9	4.5
Silvex (PGBEE) +	2 lb ai (surface acre)			
Molasses	2 gal (surface acre)			
2,4-D (DEA) +	2 lb ai (surface acre)	7/6	8.3	6.3
Molasses	1 gal (surface acre)			
2,4-D (DEA) +	2 lb ai (surface acre)	7/14	5.3	3.1
Silvex (PGBEE) +	2 lb ai (surface acre)			
Molasses	2 gal (surface acre)			

* 0 denotes no control, 10 denotes complete control.

** Surface rating - uppermost parts to 1 ft.

† Subsurface rating - 1 ft to bottom.

by three research workers. All plots were rated approximately 6 weeks after treatment.

53. Of particular interest was the increased control obtained by applying the 2,4-D (DEA) and molasses combination over that realized when silvex was added to this mixture. However, this was not the case with 2,4-D (PGBEE).

54. Subsurface ratings in Table D19 indicate the need for more

efficient herbicide placement and contact with the lower portions of egeria as discussed previously. Injection of diquat to approximately 24 in. into the mats of egeria failed to accomplish complete dispersal and control down to the hydrosol.

55. In earlier field tests rectangular shaped plots were used to determine the effectiveness of herbicides for control of egeria. In these studies the herbicides were applied from a boat powered by a small outboard motor. However, the maneuverability and the rate of movement of the boat was extremely limited due to the dense growth of submersed weeds. Thus, the uniform distribution of herbicides to the experimental plots by this method was impaired.

56. In order to alleviate these difficulties for subsequent field experiments, a small air-boat motor was obtained to replace the outboard motor. This allowed the spray boat to move freely over areas infested with submersed weeds. Additionally, it was discovered that if the experimental plot was circular in shape instead of rectangular that the herbicides could be applied more uniformly and the application time was less.

57. A schematic diagram of the circular plot technique is presented in Figure D1. A stake was located in the center of the plot and one end of a floating rope was attached to the stake. The other end of the rope was attached to a pulley located at the front of the boat for unwinding the rope after each 3-ft circular pass. A 3-ft radius was used since the width of the spray boom was 3 ft. To insure proper radius for uniform distribution of herbicides, flagging was used to mark the rope at 3-ft intervals.

58. Two field experiments were conducted during the summer of 1972 to evaluate the effectiveness of several herbicides on control of egeria. The herbicides tested were those which had shown significant control of egeria in earlier pool studies.

59. A suitable experimental area having a dense stand of egeria was located in Lake Martin, a shallow lake with an average depth of 6-8 ft. In addition, lesser infestations of Ceratophyllum and Utricularia were present in the experimental area.

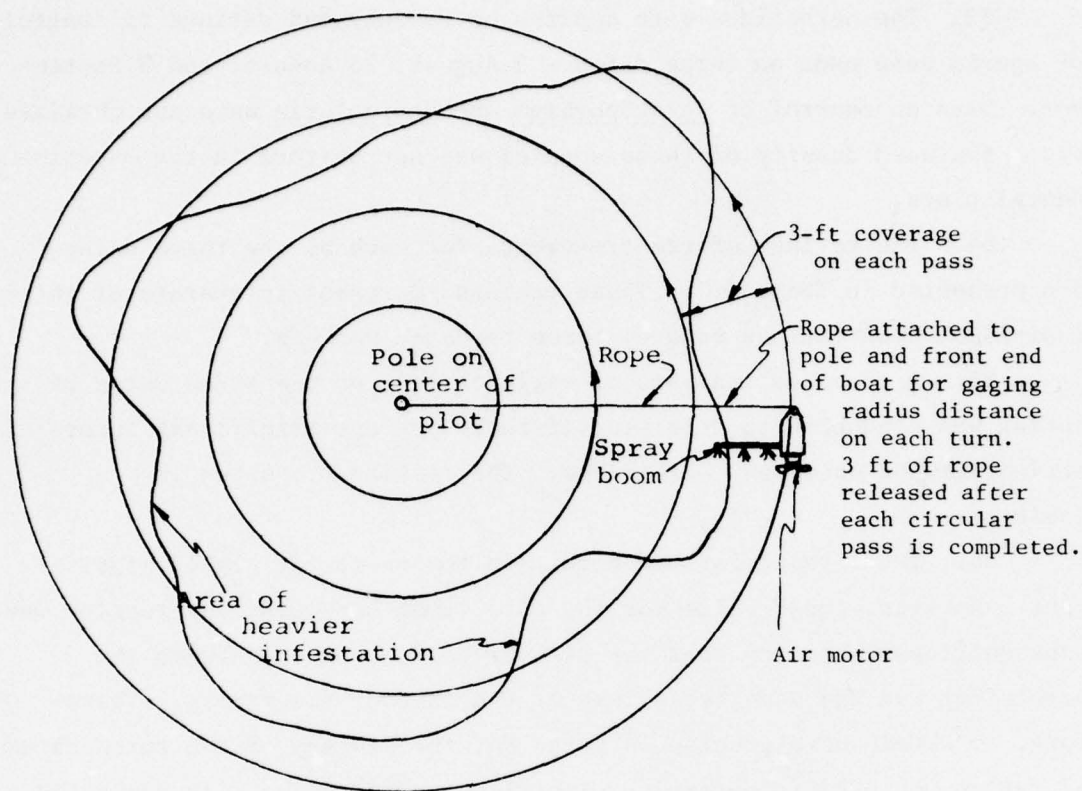


Figure D1. Typical circular plot layout showing spray patterns which proved most successful in field trials

60. Eight herbicide treatments and a check were included in the test and were arranged in completely randomized design with two replications per treatment. The calculated rate of each herbicide applied was based upon pounds of active ingredient per acre of surface area.

61. Circular plots as described earlier, with a radius of 29.3 ft and an area of 2700 sq ft were used for each treatment. The circular plots were used as this technique speeded the operation and enabled more precise application of the chemicals.

62. Chemicals were mixed into a water volume equivalent to 300 gpa and injected into the mats of egeria by holding the spray boom

just above the water surface. A special straight-jet nozzle was used to inject the solution to about 24 in. deep at 100 psi.

63. The herbicides were applied on 20 July and ratings on control of egeria were made on three dates - 3 August, 23 August, and 9 September. Data on control of Ceratophyllum and Utricularia were not obtained since the weed density of these species was not uniform in the experimental plots.

64. The ratings of the treatments for each of the three dates are presented in Table D20. These ratings represent an average of three individual observations made by three research workers.

65. A combined analysis of variance test of the three dates of rating was conducted to determine if there was any significant interaction between dates and herbicides. The results are shown in Table D21.

66. The F value for the herbicide component was highly significant. However, the F value for the date times herbicide interaction was nonsignificant, meaning that the difference in control between the herbicides was the same regardless of the date of the rating. Therefore, to obtain more precise information, the average of the three dates of rating was used to determine significant differences. In Table D22 are presented the means of the three dates combined.

67. Four of the treatments gave significant control of egeria when compared with the check. These treatments were Fenac (10 lb ai), fenac (10 lb ai) + Cu (2.7 lb ai), diquat (1.36 lb ai) + Cu (2.7 lb ai), and diquat (2.7 lb ai) + Cu (2.7 lb ai). However, there were no significant differences among these four treatments.

68. The treatments involving 2,4-D alone and in combination with other chemicals gave significantly less control than did the other herbicide treatments tested. In addition, the 2,4-D treatments were not significantly different from the check.

69. Based on the results obtained from this experiment it may be concluded that fenac and diquat gave the best control of egeria. The addition of Cu to fenac did not enhance its effectiveness. The 1.36 lb ai/A rate (0.5 ppm) of diquat was as effective as the 2.7 lb ai/A rate

Table D20
Ratings of Herbicides for Each of Three Dates

<u>Herbicide and Application Rate</u>	<u>Rating at Indicated Date*</u>		
	<u>8/3</u>	<u>8/23</u>	<u>9/7</u>
Check	2.3	2.5	3.0
Fenac (10 lb ai)	5.0	9.0	9.5
Fenac (10 lb ai) + Cu (2.7 lb ai)	5.8	8.5	9.0
Diquat (1.36 lb ai) + Cu (2.7 lb ai)	5.8	9.0	8.5
Diquat (2.7 lb ai) + Cu (2.7 lb ai)	5.5	7.0	7.0
2,4-D (2 lb ai) + silvex (2 lb ai) + molasses (2 gal)	2.5	5.5	2.5
2,4-D (4 lb ai) + Ethephon (0.1 lb ai)	3.8	3.0	2.5
2,4-D (4 lb ai)	4.5	5.5	2.5

* 0 denotes no control, 10 denotes complete kill.

Table D21
Combined Analysis of Variance Table for Each of Three Dates

<u>Sources of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>
Dates	2	28.8	14.4	
Herbicides	7	219.9	31.4	11.17
Dates Times Herbicide Interaction	14	46.3	3.31	1.18*
Error	24	67.5	3.81	

* Nonsignificant.

Table D22
Mean Rating for Three Dates

<u>Herbicide and Application Rate</u>	<u>Mean*</u>
Fenac (10 lb ai)	7.8 a
Fenac (10 lb ai) + Cu (2.7 lb ai)	7.8 a
Diquat (1.36 lb ai) + Cu (2.7 lb ai)	7.8 a
Diquat (2.7 lb ai) + Cu (2.7 lb ai)	6.5 a
2,4-D (4 lb ai)	4.1 b
2,4-D (2 lb ai) + silvex (2 lb ai) + Molasses (2 gal)	3.5 b
2,4-D (4 lb ai) + ethephon (0.1 lb ai)	3.1 b
Check	2.6 b

* All means which are followed by a letter in common do not differ significantly at the 5 percent level of probability. 0 denotes no control, 10 denotes complete control.

(0.1 ppm). Combinations of 2,4-D with silvex or with ethephon and 2,4-D alone did not give significant control over that of the check.

70. In another series of small field plots three herbicide treatments and a check treatment were arranged in a completely randomized design with two replications of each treatment. The rate of each herbicide applied is reported as pounds of active ingredient per acre of surface area.

71. The size of each plot was 0.1 acre and was circular in shape. Herbicides were mixed with water and applied at a rate of 300 gpa. In an attempt at deep placement the herbicides were applied through three 15-ft hoses weighted with lead filled pipes which trailed behind the boat. Due to the density of weed growth the weighted hoses did not descend below 3 ft and the herbicides were injected at this level.

72. The herbicides were applied on 27 July and the treatments were evaluated on 3 August, 23 August, and 7 September.

73. Table D23 contains the ratings of each treatment for each of the three dates. The ratings for each date were based upon the average evaluations of three research personnel.

74. In order to determine if there was an interaction between

Table D23
Rating of Each Herbicide for Each of Three Dates

<u>Herbicide and Application Rate</u>	<u>Rating at Indicated Date*</u>		
	<u>8-3</u>	<u>8-23</u>	<u>9-7</u>
Check	4.5	4.0	3.0
Diquat (2.7 lb ai)	4.7	9.0	9.0
Diquat (2.7 lb ai) + Cu (2.7 lb ai)	8.0	8.0	8.0
TD 1874	5.5	7.0	6.0

* 0 denotes no control, 10 denotes complete control.

dates times herbicides, a combined analysis of variance test was calculated. The results are presented in Table D24.

75. The F value for interaction was nonsignificant while the F value for the herbicide component was highly significant. Therefore, comparisons between treatments were based on the average rating for the three dates and are presented in Table D25.

76. The diquat (2.7 lb ai) + Cu (2.7 lb ai) and diquat (2.7 lb ai) treatments gave significantly better control than did TD 1874 and the check. However, the difference between the two diquat treatments was nonsignificant.

77. TD 1874 was significantly superior to the check but gave significantly less control than did either diquat or diquat + Cu.

78. Diquat gave the best control of egeria and its effectiveness was not increased by the addition of Cu. TD 1874 gave partial control, but it was not as effective as either diquat or diquat + Cu.

Large-Scale Field Testing

79. Field testing efforts were intensified in 1973 as prescribed for the third year of this project. Herbicides which showed promise in pool screening studies or in earlier field studies were included in experiments conducted at Lake Martin near LaFayette, Louisiana, and

Table D24
Combined Analysis of Variance Table for the Three Dates

<u>Sources of Variation</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Square</u>	<u>F</u>
Dates	2	7.0	3.5	
Herbicide	3	63.6	21.2	16.3
Dates times herbicide interaction	6	21.8	3.6	2.8*
Error	12	15.6	1.3	

* Nonsignificant.

Table D25
Means of Rating for Three Dates Combined

<u>Herbicide and Application Rate</u>	<u>Mean*</u>
Diquat (2.7 lb ai) + Cu (2.7 lb ai)	8.0 a
Diquat (2.7 lb ai)	7.5 a
TD 1874	6.3 b
Check	3.8 c

* All means which are followed by a letter in common do not differ significantly at the 5 percent level of probability.

at Black Lake near Natchitoches, Louisiana.

Black Lake experiment

80. A site at the north end of Black Lake where dense stands of egeria grew during the summer and fall of 1972 was chosen for the 1973 experiment. Treatments were applied on 16 and 17 March 1973, when the water temperature had risen above 60°F in the plot area. At this time the egeria was on the bottom of the lake and had not yet begun to rise in the water or to make new vegetative growth. The reason for this timing was to expose the weed to herbicide treatment after the stress of winter was over and just prior to spring growth. It was reasoned that at this point the plant would be in a weakened state and most vulnerable to herbicide treatment.

81. Treatments were applied to circular plots having an area of 0.09 acre and a depth ranging from 6 to 10 ft. Each plot was replicated twice. Treatments and pounds of active ingredients per acre applied are listed in Table D26.

Table D26

Herbicide Treatments Applied at Black Lake 16 and 17 March 1973

<u>Treatment</u>	<u>Rate, lb ai/A</u>
Check nontreated	--
Diquat	2.0
Diquat	4.0
K-lox	1.6 Cu ion
K-lox	3.2 Cu ion
Diquat + K-lox	2.0 + 1.6 Cu ion
Diquat + K-lox	4.0 + 1.6 Cu ion
Diquat + K-lox	4.0 + 3.2 Cu ion
Diquat + K-lox + fenac	2.0 + 1.6 Cu ion + 10.0
Fenac	10.0
Fenac	20.0
3M System E	13.4
3M System E	26.8

82. Heavy rains occurred shortly prior to and following the date of treatment, causing the water to rise to the flood stage in Black Lake and many other regions of the state. Water remained over the plot markers for several weeks. Observations of plots after the waters receded revealed no egeria present in the plot area, and only limited stands of this aquatic plant could be found in Black Lake in general. It is speculated that a drawdown during the fall followed by the prolonged flooding with silt-laden water was related to the disappearance of egeria from the areas where it grew profusely the previous year. Due to the absence of egeria in the plot area, evaluations of the effectiveness of treatments were of no value.

Lake Martin experiments

83. Three aquatic herbicide experiments were conducted at Lake Martin during the spring and summer of 1973. In order to distinguish between experiments they will be referred to as experiments A, B, and C.

84. Experiment A. The herbicide treatments listed in Table D27 were applied with weighted hoses on 20 and 21 June 1973, to circular plots having an area of 0.09 acre and an approximate depth of 10 ft. The experiment was a completely randomized design and included duplicate plots for each treatment. Herbicides were applied in a volume of water equal to 200 gpa through trailing hoses. Due to the density of egeria and other aquatic growth, the weighted hoses employed did not descend below a depth of 5-8 ft.

85. At the time of application water temperatures were 84°F 1 ft below the surface and 73°F at the lake bottom. Weed density in the plots ranged from moderately dense to very dense at the beginning of the experiment.

86. Plots were rated visually for egeria control 35, 45, and 55 days after application. An analysis of variance indicated that differences between treatments were not statistically significant. The treatments tested and means for ratings of treatments after 55 days are shown in Table D27.

87. Diquat alone and in a tank mix with K-lox (copper hydroxide triethanolamine complex) provided the highest control ratings. TD 1874

Table D27
Evaluation of Herbicide for Control of Egeria densa
in Lake Martin (Experiment A)

<u>Treatments</u>	<u>Rate, lb ai/A</u>	<u>Ratings*</u>
Check	--	1.0
Diquat	2.0 Cu ion	9.0
Diquat + K-lox	2.0 + 1.6 Cu ion	7.5
K-lox	1.6 Cu ion	3.5
Fenac	10.0	0.0
Fenac	20.0	3.5
TD-1874	10.0	6.0
TD-1929	10.0	6.0

Note: F value nonsignificant.

* 0 denotes no control, 10 denotes complete control.

and TD 1929, two experimental endothall derivatives supplied by the Pennwalt Corporation, were slightly less effective. Control for fenac at 10 and 20 lb ai/A was poor and inconsistent with the results for pool and field studies conducted in 1972. K-lox alone provided less control of egeria than did K-lox in combination with diquat. Water hyacinths moved over the plots and prohibited further evaluation for this study after the 55-day rating.

88. Experiment B. In earlier pool studies 3M System E (dihydroxy aluminum salt of endothall) showed little herbicidal activity on egeria when applied at rates equivalent to 16.5 and 33 lb ai/A. Since this herbicide was already registered for aquatic use, a small experiment was conducted to gain information on the effectiveness of System E for egeria control under field conditions at a higher rate suggested by the manufacturer. In this study the System E pellets were applied to two 1/2-acre plots at a rate equivalent to 200 lb of formulation per acre (44.2 lb ai/A). Two 1/2-acre check plots were also included in the experiment. Both check and treated plots were located in water approximately 8 ft deep and densely covered with egeria.

89. Treatments were applied on 7 June 1973, and plots were rated visually on 13 and 25 July. There was no evidence of any control on either date. Later ratings were prohibited due to coverage of the plot area with water hyacinths shortly after the date of the second evaluation.

90. Based upon results of earlier pool studies and this field test, it was concluded that 3M System E was of no practical value for control of egeria. Testing of this formulation was therefore discontinued.

91. Experiment C. On 13 and 14 August 1973, the herbicide treatments listed in Table D28 were applied on 1/2-acre circular plots. The test area was approximately 10-12 ft deep and was covered with a dense stand of egeria along with scattered coontail, cabomba, and bladderwort. A completely randomized experimental design was used with two replications per treatment.

Table D28
Ratings of Herbicide Effectiveness
for Experiment C

<u>Herbicide</u>	<u>Rate/A</u>	<u>Mean Ratings of</u> <u>Herbicidal Activity</u> <u>at Indicated Date*</u>	
		<u>9/29/73</u>	<u>10/5/73</u>
Compound K	8 gal	8.5	10.0
Diquat + K-lox	2 gal + 4 gal	6.5	9.5
Diquat + Compound K	2 gal + 4 gal	5.5	8.0
K-lox	8 gal	2.5	7.0
Diquat	2 gal	4.5	4.5
Check - nontreated	--	1.5	3.0
SD 16389	1.5 lb ai	0.0	2.5

* 0 denotes no control, and 10 denotes complete control. Means which are followed by a bar in common do not differ significantly at the 5 percent level of probability.

82. Heavy rains occurred shortly prior to and following the date of treatment, causing the water to rise to the flood stage in Black Lake and many other regions of the state. Water remained over the plot markers for several weeks. Observations of plots after the waters receded revealed no egeria present in the plot area, and only limited stands of this aquatic plant could be found in Black Lake in general. It is speculated that a drawdown during the fall followed by the prolonged flooding with silt-laden water was related to the disappearance of egeria from the areas where it grew profusely the previous year. Due to the absence of egeria in the plot area, evaluations of the effectiveness of treatments were of no value.

Lake Martin experiments

83. Three aquatic herbicide experiments were conducted at Lake Martin during the spring and summer of 1973. In order to distinguish between experiments they will be referred to as experiments A, B, and C.

84. Experiment A. The herbicide treatments listed in Table D27 were applied with weighted hoses on 20 and 21 June 1973, to circular plots having an area of 0.09 acre and an approximate depth of 10 ft. The experiment was a completely randomized design and included duplicate plots for each treatment. Herbicides were applied in a volume of water equal to 200 gpa through trailing hoses. Due to the density of egeria and other aquatic growth, the weighted hoses employed did not descend below a depth of 5-8 ft.

85. At the time of application water temperatures were 84°F 1 ft below the surface and 73°F at the lake bottom. Weed density in the plots ranged from moderately dense to very dense at the beginning of the experiment.

86. Plots were rated visually for egeria control 35, 45, and 55 days after application. An analysis of variance indicated that differences between treatments were not statistically significant. The treatments tested and means for ratings of treatments after 55 days are shown in Table D27.

87. Diquat alone and in a tank mix with K-lox (copper hydroxide triethanolamine complex) provided the highest control ratings. TD 1874

92. All treatments were applied in a volume equivalent to 200 gpa metered through weighted pipes attached to 15-ft trailing hoses. Six hoses spaced 2-ft apart were attached to a 10-ft pipe boom which covered a 12-ft swath. The boom was mounted on an air boat which traveled approximately 3 mph. The application depth varied with the density of weed growth which prevented the trailing hoses from sinking to the bottom. It was estimated that the depth of application was between 6 and 10 ft.

93. Herbicides were applied in two passes over each plot with half the dose being applied in 50 gal of water during each pass. This procedure insured a more uniform herbicide distribution pattern over the plot area.

94. Visual ratings of all plots were made on 29 August and 5 October 1973. Means for these ratings are presented in Table D28. The ratings for both dates show the superior treatment to be an experimental copper complex formulation containing 8 percent copper (Compound K) manufactured by Kennecott Copper Corporation. Compound K applied at 8 gpa (6.4 lb copper) gave perfect control when rated on 5 October. Other treatments which provided excellent control were combinations of diquat + K-lox at 2 + 4 gpa and diquat + Compound K at 2 + 4 gpa, respectively. K-lox applied in combination with diquat significantly enhanced egeria control over that noted for diquat alone at the 5 October rating. K-lox applied alone at 8 gpa (6.4 lb Cu) received a lower control rating but was not statistically different from that for the diquat-K-lox combination. The K-lox treatment was significantly less effective than Compound K when applied at equal rates.

95. SD 16389, an experimental traizine compound by Shell Oil Company, applied at 1.5 lb ai/A received the lowest rating of all plots. This was inconsistent with earlier observations in pool studies where SD 16389 provided complete control of egeria. These inconsistencies underscore the importance of field testing in a herbicide testing program. It is readily apparent that laboratory and pool studies serve only as a guide to indicate potentially effective herbicides for field use and that extensive field testing is necessary for development of

an effective herbicide control practice.

96. The lack of effectiveness for SD 16389 in the field may be associated with the greater dilution factor where 1.5 lb ai/A was applied to plots 10-12 ft deep as compared with similar applications in pools with a water depth of 1 ft. Further testing of SD 16389 will be conducted under field conditions to determine if effective rates and/or application techniques may be developed which might provide the high degree of control shown by this herbicide in pool tests.

97. The results of Experiment C were most encouraging in that they demonstrated that effective field control of egeria could be achieved with at least two herbicides.

98. Field testing of chemical control methods for egeria were less extensive in 1974 than in previous years because the main thrust of research at the University of Southwestern Louisiana was directed toward 2,4-D residue research in slowly moving waters. Field applications in 1974 included a single series of herbicide treatments applied in Lake Martin on 15 May 1974.

99. Treatments which had proven most promising in earlier laboratory, outdoor pool, and field screening studies were compared. Plot size was increased to 1 acre in area to more closely approximate a control situation. The plot area contained a dense stand of egeria along with scattered stands of coontail and cabomba. The average depth of the plots was 6-7 ft.

100. Application techniques were similar to those employed in the 1973 tests. The circular plot pattern was used, and bottom applications were made using weighted trailing hoses rigged on an air boat. Herbicides were applied in a volume of 200 gpa of water.

101. The herbicide treatments and ratings of treatments are shown in Table D29. Plot ratings were made on 29 May 1974, by an underwater diver, and the 10 July and 22 November 1974 ratings were made from the surface.

102. Table D29 shows that the best early weed control ratings were obtained with komine, diquat plus komine, diquat, diquat plus K-lox, and TD 1929. At the 10 July 1974 rating, diquat plus komine, diquat plus

Table D29
Control Ratings for Selected Herbicide
Treatments in Lake Martin

Treatments	Formulation gpa	Active Ingredient lb/A	Control Ratings at Indicated Dates*		
			5/29/74	7/10/74	11/22/74
Check, nontreated	--	--	2	2	0
Diquat	2	4	9	6	4
Komine	8	6.4 Cu ion	10	8	4
Diquat + Komine	1 + 4	2 + 3.2 Cu ion	10	10	7
Diquat + K-lox	1 + 4	2 + 3.2 Cu ion	9	9	2
Diquat + Hydrothol 191**	2 + 10	4 + 20	7	6	0
Hydrothol 191**	30	60	5	5	0
TD-1874**	9	18	4	5	0
TD-1929**	6	6	8	5	0

* 0 denotes no control, 10 denotes complete control

** Various salts of endothall supplied by Pennwalt Corporation.

K-lox, and komine alone provided the greatest degree of egeria control. At the 22 November 1974 rating, diquat plus komine showed the most persistent control with a rating of 7. Komine alone and diquat alone each had ratings of 4 and diquat plus K-lox had a rating of 2. The other treatments received a rating of 0, which indicated that egeria had completely recovered and overtaken the entire plot area.

103. The results of this observational trial along with the observations from earlier research show that the most effective herbicides for control of egeria under a natural lake situation include diquat, komine, and combinations of diquat with komine or K-lox. To obtain lasting control in a body of water heavily infested with egeria,

two or more herbicide applications are necessary. Annual treatments will be required thereafter to keep this weed pest in abatement.

Conclusion

104. The chemical approach to control of Egeria densa is costly in terms of chemical costs and application expense. Where other means of control such as drawdown or biological methods are not practical, diquat, komine, and combinations of diquat and komine or K-lox will effectively control egeria with two or more initial applications followed by an annual application. Recommended rates are 4 lb ai/A of diquat; or 6.4 lb/A of Cu ion from komine; or 2 lb ai/A of diquat plus 3.2 lb/A of Cu ion from komine or K-lox.

APPENDIX E

AQUATIC WEED CONTROL IN SMALL
RESERVOIRS WITH DIQUAT

by

Richard R. Yeo, Nathan Dechoretz, P. A. Frank,
and Edward O. Gangstad

Prepared for the
Interagency Technical Advisory Committee
Aquatic Plant Control Program
October 1974

AQUATIC WEED CONTROL IN SMALL
RESERVOIRS WITH DIQUAT *

by

Richard R. Yeo, Nathan Dechoretz, P. A. Frank,
and Edward O. Gangstad**

Introduction

Plant competition

1. Competition of desirable plants with undesirable plants frequently provides effective and economical weed control. Careful selection of adapted and desirable species or varieties and maintenance of optimum soil fertility and cultural conditions for their maximum growth are important. Mowing, pasturing with livestock, spraying with selective herbicides, liming, fertilizing, or other means of altering the environment to favor the desired species over weeds may be necessary for the most satisfactory results. Usually the desired competitive crop must be planted. In the aquatic situation, competition is affected by transparency of the water, water currents, wave action, frequency and elevation of dewatering, and chemical factors such as water hardness, pH, and availability of plant nutrients.

2. Occasionally a mixture of desirable and undesirable vegetation already established on banks of irrigation ditches, canals, streams, lakes, and other impoundments can be favorably altered with other noncultivated areas by repeated applications of selective herbicides. Under such treatment the resistant desirable species become

* Preliminary discussion presented by the senior author to the Inter-agency Technical Advisory Committee, Aquatic Plant Control Program, Callaway Gardens, Warm Springs, Georgia, 25-27 August 1971.

** Botanist, Agricultural Research Service, U. S. Department of Agriculture, University of California, Davis, California; Biological Research Assistant, Agricultural Research Service, Davis, California; Leader, Agricultural Research Service, Denver, Colorado; and Chief, Aquatic Plant Control Program, Office, Chief of Engineers, U. S. Army, Washington, D. C., respectively.

dominant and the susceptible undesirable species are gradually eliminated. The elimination of deep-rooted perennial weeds or other aggressive species often necessitates the use of drastic and frequently expensive chemical or mechanical methods. Thereafter, desirable species can be planted and suitable conditions provided for their effective competition with surviving or reinvading weeds.

3. Completed research indicates that "weedy" canals and reservoirs should be planted with spikerush [Eleocharis coloradoensis (Britt.) Gilly] for competitive aquatic weed control. The aggressiveness and extent of growths that can be developed from sod, seed, and tubers of each of the three species of spikerush should be further evaluated. Studies of methods for developing large quantities of propagules from cultures on one or more acres are needed. Reproduction and hybridization studies to develop the faster growing and more competitive hybrids should be investigated.

Mechanical methods

4. Numerous effective herbicides and improved methods of application have replaced many less effective mechanical methods of weed control. However, mechanical methods are still necessary or advantageous in many situations. Improvements in tools used for cultivating, mowing, burning, and ditch cleaning and in other machinery needed for vegetation control have coincided with improvements in chemical methods. Even the most effective chemical methods frequently must be combined with mechanical weeding to remove surviving weeds and to prevent future spread by seed or other plant parts. Water level fluctuations, mechanical weed cutters, harvesters, and hydraulic devices also have specific application to aquatic weed situations where physical barriers and topographical features are compatible or where chemicals cannot be used.

Herbicides

5. Since 1950 many chemicals have been evaluated for effectiveness as herbicides and more than 100 of these have been recommended for controlling one or more weeds. The effectiveness of herbicides on susceptible species is affected by stage of growth, soil organic matter

and pH, fertility, texture, rainfall and irrigation, water pH and chemical content, temperature of air and water, light intensity, and other soil, water, and climatic factors. Safe and effective herbicides are available for controlling many weeds growing in various environments, including cropland, rangeland, gardens, lawns, ditchbanks, and other noncrop areas and irrigation, drainage, navigable, potable, and recreational waters. Because of the many factors and principles involved and the dynamic nature of research on herbicides, information about chemical weed control is rapidly increasing and new recommendations are continually replacing old ones.

Biological agents

6. Only limited attention has been given to controlling undesirable plants by using insects, plant disease organisms, and other natural enemies. Research is now under way to discover and develop effective and safe biological agents to control such weedy species as alligator weed, water hyacinth, submersed aquatic weeds, Scotch broom, halogeton, cactus, tansy ragwort, puncturevine, gorse, and St. Johnswort. The Agasicles beetle has been used successfully for control of alligator weed in the Southern states, such as Florida, Louisiana, and Texas. Studies on other biological control agents have not progressed to the extent that they are acceptable to State and Federal agencies or that recommendations for their use are possible.

Chemical control

7. Copper sulfate was first used to control algae in 1904, and sodium arsenite was used to control water hyacinth in 1902 and submersed weeds in 1927. However, most of the herbicides now registered by the Environmental Protection Agency for use in controlling one or more aquatic weeds were discovered after 1945. Herbicides often give more effective, longer lasting, and less expensive control of aquatic weeds than do mechanical methods.

8. A few aquatic herbicides are poisonous to humans and other warm-blooded animals and must be handled and used with caution and according to special procedures. Some herbicides are toxic to fish, but most do not injure fish at concentrations required to kill weeds. Most

aquatic herbicides do not injure crops irrigated with water at concentrations required for weed control, but a few may injure crops at low concentrations.

9. Only limited information is available on the persistence and fate of herbicides in water, aquatic soil, fish, and aquatic plants. Therefore, in addition to following all general precautions for the safe use of herbicides described in the section on basic principles and methods of weed control and the special precautions in the following subsection, the user of an aquatic herbicide must follow carefully all instructions and restrictions on the label regarding aquatic situations in which the herbicide should not be used. He must know how much time should elapse after herbicide treatment before treated water may be used for drinking, fishing, swimming, and irrigating crops.

Control of submersed vegetation with diquat

10. Diquat has been recommended for the control of submersed aquatic vegetation by most workers in the field. However, errors in proper classification have resulted in confusion regarding control recommendations. While Florida elodea (*Hydrilla verticillata* Casp.) and Brazilian elodea (*Egeria densa* Planch.) are common in southern waterways, American elodea (*Elodea canadensis* Michx.) is generally found in the northern states and California. Florida elodea is the most difficult submersed aquatic weed to control. Diquat, diquat plus copper, and diquat plus endothall have been recommended for control of Florida elodea.¹⁻⁷

Fate of diquat in the aquatic environment

11. Diquat is a quaternary salt of 4,4'-bipyridyl, carrying a positive charge of 2, formulated as the dichloride or dibromide salt. It is water soluble (70 percent) and is a general weed killer used for both terrestrial and aquatic plants. It is absorbed on soils by exchange reactions up to the cation exchange capacity of the soil, and the absorption is essentially irreversible in montmorillonitic clays but partially reversible in kaolinitic clays. Apparently, only a small

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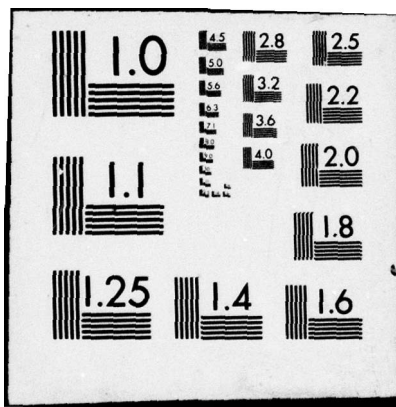
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portion of applied diquat is absorbed by aquatic weeds, and in alligator weed little further translocation of diquat occurs. There is no indication that diquat is metabolized by higher plants. No information is available on microbial degradation of diquat. Ultraviolet light rapidly degrades diquat in aqueous solutions. Diquat resists biological degradation in aquatic environments, but the presence of sorbents in the water in the form of particulate matter would greatly influence diquat persistence in the aquatic environment. Although diquat has been found in muds of pools and ponds 4 years after application, no adverse effects on adult bluegills were noted at levels of diquat applied for weed control. Diquat apparently exerts its herbicidal action by formation of a stablefree radical on introduction of an electron, the radical forming reactive hydrogen peroxide radicals on reoxidation. The hydrogen peroxide radicals accumulate and destroy plant cells.⁸⁻¹²

Research Investigations of Aquatic Weed Control*

Control of submersed aquatic weeds

12. Six small reservoirs were obtained for studies involving the control of submersed aquatic weeds, dissipation of the herbicides used to control the vegetation, effect of the herbicide-treated water on turf grasses, and effects on fish. The reservoirs were located at the El Macero Golf Course near Davis, California, the Riverbend Golf Course near West Sacramento, California, and the Auburn Valley Golf Course near Auburn, California.

13. The kinds of aquatic weeds growing in the various reservoirs included horned pondweed (Zannichellia palustris L.), curleyleaf pondweed (Potamogeton crispus L.), sago pondweed (P. pectinatus L.), water milfoil (Myriophyllum spicatum var. exalbescens Jep.), American elodea (Elodea canadensis Michx.), coontail (Ceratophyllum demersum L.), California waterprimrose [Ludwigia peploides (HBK) Raven], and chara (Chara spp.).

* From Annual Report, 1972. R. R. Yeo, U. S. Department of Agriculture, Agricultural Research Service, Botany Department, University of California, Davis, California.

14. The different kinds of fish inhabiting the reservoirs were green sunfish (Lepomis cyanellus Raf.), redear sunfish (L. microlophus Gunther), smallmouth bass (Micropterus dolomieu Lacepede), golden shiner [Notemigonus crysoleucas (Mitch.)], mosquitofish [Gambusia affinis (Baird and Girard)], and common carp (Cyprinus carpio L.).

Materials and methods

15. Table E1 shows the locations and dates of applications of mixtures of diquat plus copper sulfate pentahydrate (CSP), hereafter referred to as dicop.

Table E1
Applications of Diquat Plus CSP

<u>Location</u>	<u>Dates of Application</u>
El Macero #1	5/9/72, 7/25/72, 8/25/72
Auburn Valley #1	5/8/72, 7/17/72, 8/21/72
Riverbend #1	5/8/72, 7/17/72, 8/25/72

16. The dicop was applied using 100 ppb of diquat plus 300 ppb copper ion. Alicop was applied at 500 ppb of aliquat 4 plus 500 ppb of copper ion. These applications were made when the initial growths or regrowths were 12-24 in. in height. Each application was made by slowly pouring the liquid mixtures into the water beside the boat and allowing the prop wash of the outboard motor to mix the chemicals. A crisscross pattern of application was used to obtain uniform distribution.

17. Four 1-qt samples of water treated with dicop and alicop were collected from different sites in each reservoir 1, 2, 3, and 4 days after application. Samples of dichlobenil-treated water were collected 1, 15, 30, 60, and 90 days after application. The samples were immediately frozen to preserve them for chemical analysis.

18. To determine the effect on turf grasses 1-, 2-, and 4-gal samples of treated water were also collected on each sampling date and

applied to the turf grasses growing at or nearest each location. The grass plots were each 2 by 4 ft. Each irrigation was replicated four times. The following kinds of grasses were irrigated at the different locations: El Macero--creeping bentgrass (Agrostis stolonifera L.), bermudagrass (Cynodon dactylon L.), and Kentucky bluegrass (Poa pratensis L.); Auburn Valley--creeping bentgrass (A. stolonifera L.) and colonial bentgrass (Agrostis tenuis Huds.); Riverbend--creeping bentgrass (A. stolonifera L.) and colonial bentgrass (A. tenuis Huds.).

19. The diquat, aliquat 4, and copper ion were analyzed separately. The diquat analysis was made using a method described by the Chevron Chemical Company.¹³ The method involved concentrating the diquat on an exchange resin 25 times, leaching the diquat from the resin, adding sodium dithionite to obtain a color reaction, determining the optical density on a Bausch and Lomb Spectronic 70, and calculating the concentration of diquat from a standard curve. The residue data from the four samples collected from each pond on each sampling date were totaled and averaged.

20. The data for diquat are shown in the following figures. Each treatment at each location is shown in Figures 1-3, the average of the treatments made at each location in Figure 4, and the average of all treatments in Figure 5. The copper analysis was made using the photo-spectronic method described in Standard Techniques Water Quality Analysis.* The residue data for the copper are shown in Figures 6-10. Each treatment at each location is shown in Figures 6-8, the average of the treatments made at each location in Figure 9, and the average of all treatments in Figure 10.

Results and discussion

21. The average of the nine treatments (three treatments at each of three sites) showed the diquat dissipated to near nondetectable levels after 4 days. Two-thirds of the diquat disappeared after 1 day, indicating rapid adsorption by the aquatic vegetation, soil, and

* Chevron Chemical Company, Ortho Division (formerly California Chemical Company). 1961. Analysis of diquat, residue method RM-5A, Richmond, California.

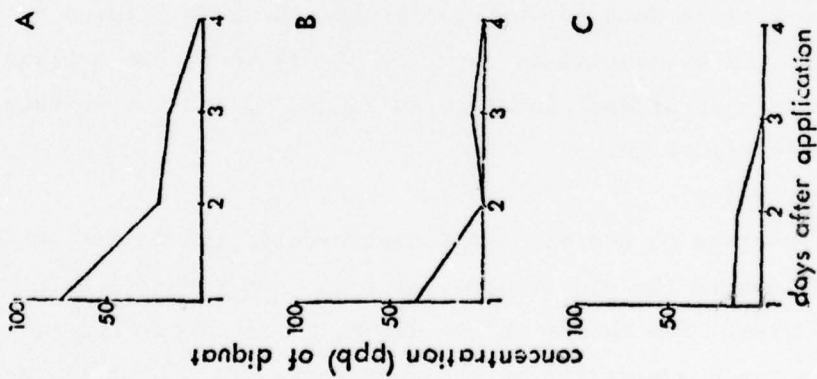


Figure E1. Dissipation of three applications of diquat (in dicop) from Auburn Valley Reservoir #1

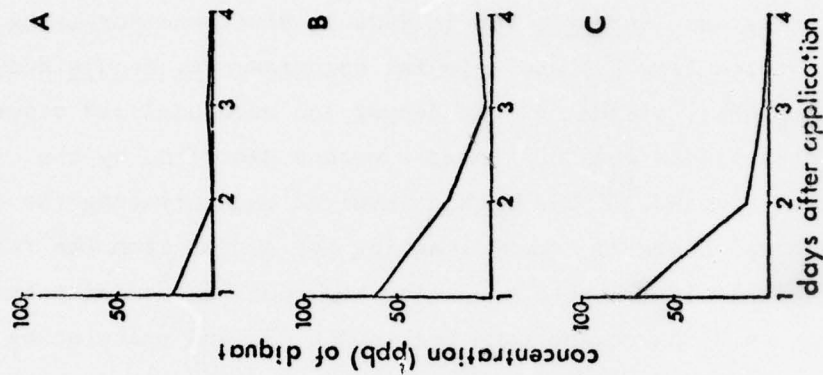


Figure E2. Dissipation of three applications of diquat (in dicop) from El Macero Reservoir

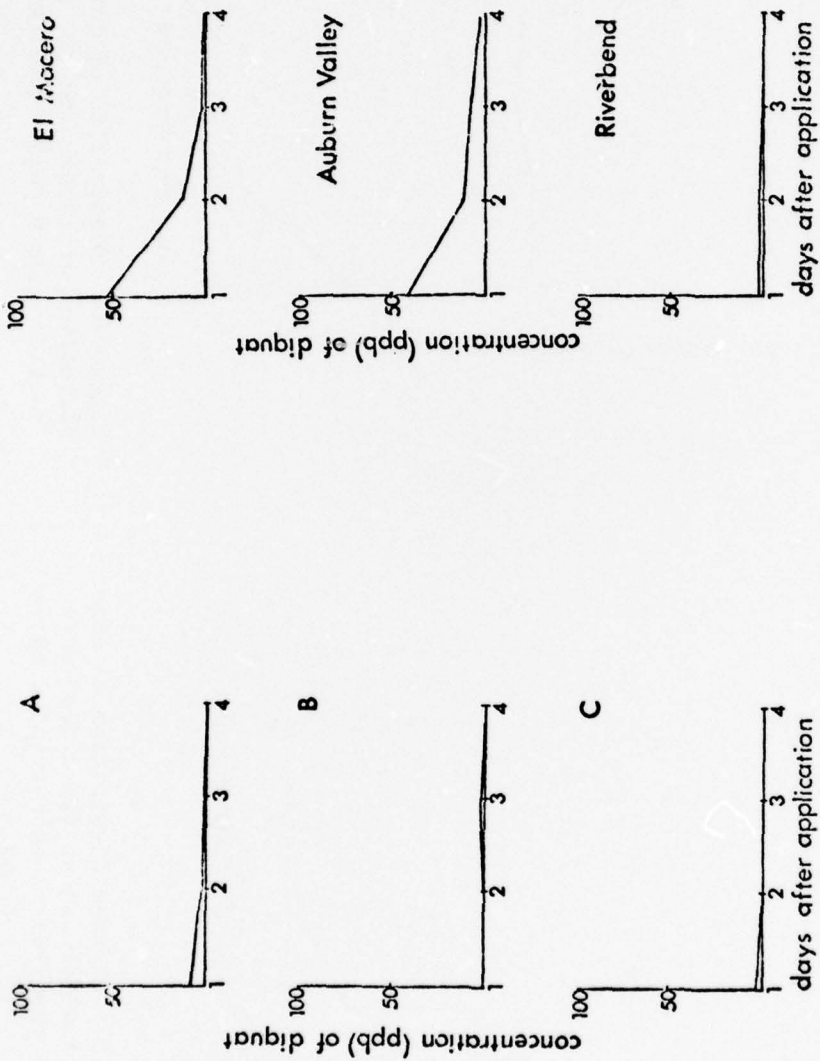


Figure E3. Dissipation of three applications of diquat (in dicop) from Riverbend Reservoir

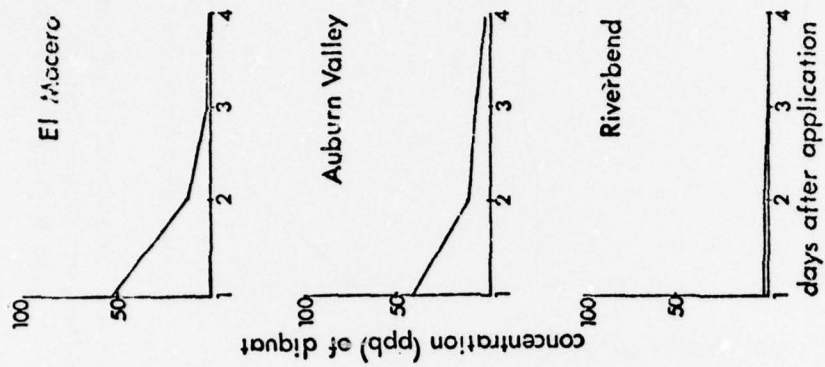


Figure E4. Average dissipation of diquat (in dicop) in each of three reservoirs each treated three times

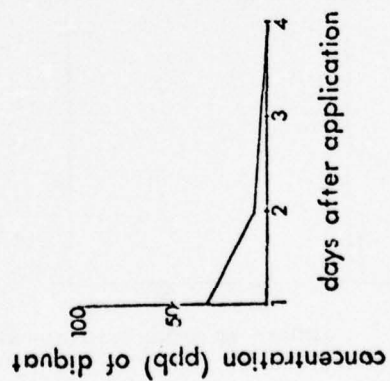


Figure E5. Average dissipation of nine applications of diquat (in dicop) made in three reservoirs, each treated three times

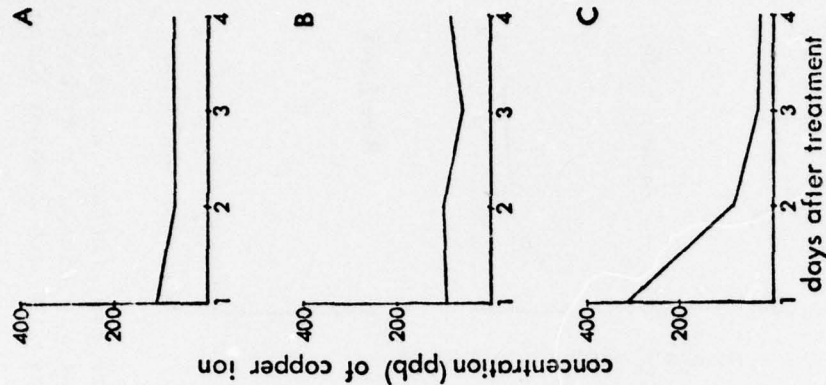


Figure E6. Dissipation of three applications of copper ion (in dicop) from Auburn Valley Reservoir

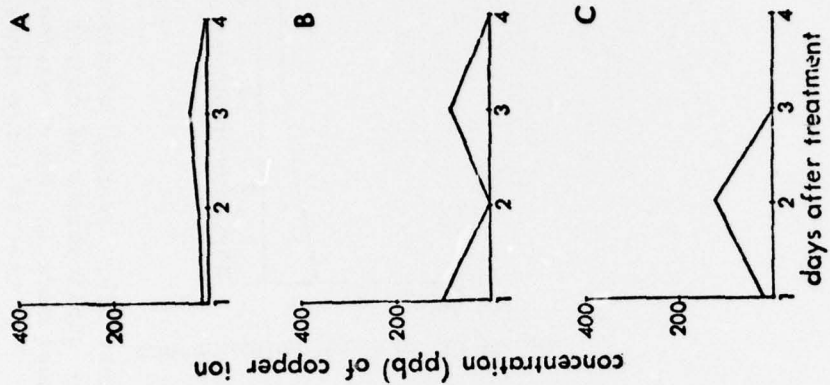


Figure E8. Dissipation of three applications of copper ion (in dicop) from Riverbend Reservoir

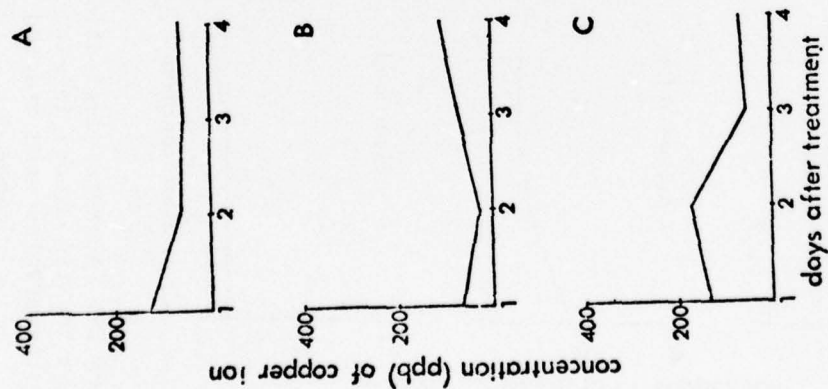


Figure E7. Dissipation of three applications of copper ion (in dicop) from El Macaro Reservoir

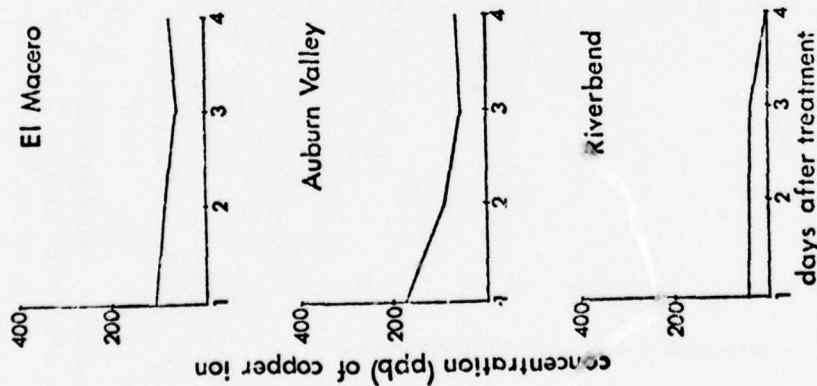


Figure E9. Average dissipation of copper ion (in dicop) in each of three reservoirs each treated three times

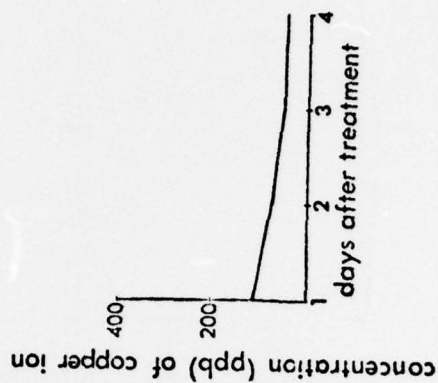


Figure E10. Average dissipation of copper ion (in nine applications of dicop) made in three reservoirs each treated three times

detritis. Almost all the diquat dissipated from Riverbend #1 the first day. The water in this reservoir had the highest nutrient levels of the three sites. Consequently, it had more planktonic organisms to adsorb the diquat. This did not alter the effectiveness of the treatment in controlling the aquatic weeds. All treatments of dicop killed the aquatic weed growth in each reservoir.

22. Fifty golden shiners were killed after the second day of the first treatment in the Riverbend Reservoir #1. Subsequent treatments in the same reservoir and at the same rate did not harm the remaining shiners. No other fish showed stress or injury in the other dicop treatments.

23. None of the grasses showed any injury from being irrigated with treated water from the different reservoirs.

24. An average of all nine treatments showed copper ion dissipated to 47 ppb in 4 days. The pattern of dissipation of copper ion was similar to that of diquat; two-thirds of the applied copper disappeared after 1 day. Also, most of the copper disappeared after 4 days, in the Riverbend Reservoir.

Residues in Crops Irrigated with Water Containing Diquat*

Methods and materials

25. Six crops were grown in the greenhouse in fertilized loam soil. Except for potatoes, seedlings were thinned to an appropriate stand after emergence of the crops. A random block design was used throughout the experiment. Crops used in the experiment were potatoes, grain sorghum, soybeans, Romaine lettuce, carrots, and onions.

26. Two irrigation methods were used to apply the herbicides to the crops--simulated overhead sprinkler and soil irrigation. The simulated overhead sprinkler method was developed during this study and was modified as the work progressed. For the potato crop, which was grown first, 10 ml of each herbicide solution was applied directly on

* From Reference 14.

the foliage of each plant. However, a new method was developed after the potato crops had been treated. This new method, which was used for all the other crops, was as follows: Every 3 min during a 4-hr period, each plant received drops of water from an overhead sprinkling can such that at the end of the treatment period one acre-in. of solution had been applied. Because of the frequency of the relatively small individual applications, the plants were wet throughout the treatment period. It is felt that this method closely simulates the type of irrigation achieved with a Rainbird sprinkler. Treatment rates for the various crops are given in Table E2.

27. In the simulated soil irrigation method of herbicide application, the irrigation solution in an amount sufficient to provide 1 acre-in. of water was applied to each crock. The dimensions of the crocks were such that 1 ℓ per crock provided 1 acre-in.

Treatment of crops

28. Crops used in this experiment were treated as follows:

- a. Potatoes - White potatoes were grown from seed pieces in 5-gal glazed crocks. The early application of the herbicides was made 117 days after planting when tubers were just beginning to develop. The potatoes were harvested 10 days after treatment (127 days after planting). Considerable variability in tuber size was observed. Another group of potato plants, grown at the same time, was treated with the herbicide solutions 158 days after planting. The potatoes treated at the more mature stage were harvested 168 days after planting. Considerable variability in tuber size was also observed in these potatoes.
- b. Grain Sorghum - An early-maturing, dwarf variety of grain sorghum (NK-22) was selected for greenhouse planting. Seeds were planted in fertilized soil in 2-gal glazed crocks. A single plant was grown in each crock. The early application of the herbicide was made 55 days after planting, i.e., the point in plant development when the most advanced grain in the developing panicle was in the milk stage. Most of the sorghum plants had two or more tillers, some of which were considered to be in the early boot stage. The late application of the same herbicide was made on another group of sorghum plants 77 days after

Table E2
Diquat Crop Treatment Data

Crops	Type of Irrigation	lb/acre	Diquat Irrigation Data		
			Concentration in 1-acre-in. H ₂ O (ppm)	mg/crock	Concentration in 10 mL H ₂ O (ppm)
Potatoes	Overhead	0.75	3.33	6.0	600
		0.15	0.67	1.2	120
	Soil	0.75	3.33	6.0	--
		0.15	0.67	1.2	--
Sorghum, soybeans, lettuce, early carrots	Overhead	0.10	0.45	0.45	
		0.02	0.09	0.09	
Late carrots	Overhead	0.10	0.45	0.45	
		0.02	0.09	0.09	
Onions	Soil	0.50	2.25	2.25	
		0.10	0.45	0.45	
		0.50	2.25	2.25	
		0.10	0.45	0.45	

planting, the point in plant development when the most advanced grain in the panicle was in the firm-to-hard dough stage. All sorghum plants were harvested 87 days after planting. Harvesting consisted of severing all plants at the crown and separately weighing and bagging the grain and chopped foliage. Both foliage and grain samples were immediately frozen after collection and weighing.

- c. Soybeans - The Hawkeye 63 variety of soybeans was selected for greenhouse planting. Seeds were planted in fertilized soil in 2-gal crocks. A single plant was grown in each crock. The early application of the herbicide was made 44 days after planting during what would be considered the early pod stage, i.e., when the most advanced inflorescences had set fruit. Upper portions of the soybean plants were still flowering profusely. The late application of the same herbicide was made on another group of soybean plants 92 days after planting during what would be considered the mature pod stage, i.e., when pods on the lower portions of the plants were turning yellow. Even though the lower leaves had begun to change color, most of the foliage and upper pods were still green. Early soybean plants were harvested 107 and late plants 118 days after planting. Beans were shelled and kept frozen at approximately 0°F until analyzed.
- d. Romaine Lettuce - Romaine lettuce was cultured in 2-gal glazed crocks. Each crock contained three plants. Treatments at the early stage of plant development was made 42 days after planting when the leaves had begun to cup. Treatment at the mature stage of growth was made 55 days after planting when leaves were densely cupped. Both early- and late-treated Romaine lettuce plants were harvested, bagged, weighed, and frozen 60 days after planting.
- e. Six carrot plants (var. Imperator) were grown in each 2-gal glazed crock. The group of carrots selected for the early application of herbicide solution was treated 56 days after seeding. Before the group of mature carrot plants was treated, an evaluation of herbicidal concentrations was made. Subsequent treatment concentrations were increased to five times that used on previous crops. These higher concentrations were applied to the mature carrot plants 89 days after seeding. All carrot

plants were harvested 103 days after seeding.

- f. Onions - White, sweet Spanish onions (Burpee-5274) were planted in 2-gal glazed crocks. Each crock had at least three vigorous plants and the herbicidal solution was applied to the group of plants considered to be in an early stage of development 78 days after planting. Bulbs were beginning to swell and were approximately 1/4-1/2 in. in diameter. Herbicidal solution was applied to the group of plants considered to be in a mature stage of development 115 days after planting. Bulbs were well developed at this stage (approximately 1/2 in. in diameter) but were not considered to be "drying-off." Concentrations of the herbicides were identical with those applied to the carrots at the mature stage of development. All onions were harvested 125 days after seeding. The foliage was weighed and discarded along with the roots. The bulbs were washed to remove residual soil, weighed, and placed in polyethylene bags for freezer storage until analysis.

Residue analysis

29. Methods of analysis. The methods of analysis for residues of the diquat included in this study were based largely on methods previously reported in the literature.¹⁵ It was necessary to modify or adapt these methods to the crop-herbicide combination involved in our studies before reliable results could be achieved.

30. Results of analysis. Diquat residue results are summarized in Table E3 and the individual crop data are given in Tables E4-8. No diquat was detected in any of the crops studied within the limits of the sensitivity of the method.

Table E3
Diquat Residues in Several Crops

Crop	Irrigation	Herbicide Application Data			Diquat Residue, ppm*	
		Rate ppm	Stage of Maturity of Crop	Days Before Harvest		
Potatoes	Sprinkler	0.67	Late	10	< 0.05	(2)
	Soil	0.67	Late	10	< 0.05	(2)
Sorghum	Sprinkler	0.45	Early	32	< 0.1	(3)
	Sprinkler	0.45	Late	10	< 0.1	(3)
	Soil	0.45	Early	32	< 0.1	(3)
	Soil	0.45	Late	10	< 0.1	(2)
Soybeans	Soil	0.45	Early	63	< 0.1	(3)
	Soil	0.45	Late	26	< 0.1	(2)
	Soil	0.09	Late	26	< 0.1	(2)
	Sprinkler	0.45	Early	63	< 0.1	(3)
	Sprinkler	0.45	Late	26	< 0.1	(2)
Carrots	Sprinkler	0.09	Early	47	< 0.05	(4)
	Sprinkler	0.45	Late	14	< 0.05	(3)
	Sprinkler	2.25	Late	14	< 0.05	(4)
	Soil	2.25	Late	14	< 0.05	(4)
Lettuce	Soil	0.09	Late	5	< 0.05	(3)
	Sprinkler	0.09	Late	5	< 0.05	(4)
	Soil	0.45	Late	5	< 0.05	(3)
	Sprinkler	0.45	Late	5	< 0.05	(4)
Onions	Soil	2.25	Late	10	< 0.05	(4)
	Sprinkler	2.25	Late	10	< 0.05	(4)
	Soil	0.45	Late	10	< 0.05	(4)
	Sprinkler	0.45	Late	10	< 0.05	(4)

* Numbers in parentheses are numbers of results averaged. None detected within the limit of sensitivity of the method of analysis.

Table E4

Diquat Residues in Potato Tubers

Sample No.	Type of Irrigation	Diquat Application Rate		Stage of Maturity of Crop at Time of Application	Weight of Potatoes Harvested		Diquat* Concentration ppm
		lb/acre	Concentration in 1-acre-in. H ₂ O, ppm		g	Weight of Sample Analyzed g	
348	Overhead	0.15	0.67	Late	191	125	0.05
349	Overhead	0.15	0.67	Late	122	122	0.05
350	Soil	0.15	0.67	Late	153	125	0.05
351	Soil	0.15	0.67	Late	307	125	0.05
Control	--	--	--	--	--	--	0.05
Control	--	--	--	--	--	--	0.05

* Practical limit of detection was 0.05 ppm of diquat.

Table E5
Diquat Residues in Soybeans

Sample No.	Type of Irrigation	Diquat Application Rate		Stage of Maturity of Crop at Time of Application	Weight of Sample Analyzed g	Diquat Concentration ppm
		lb/acre	Concentration in 1-acre-in. H ₂ O, ppm			
397	Soil	0.10	0.45	Early	25	< 0.1
398	Soil	0.10	0.45	Early	25	< 0.1
399	Soil	0.10	0.45	Early	25	< 0.1
400	Soil	0.10	0.45	Late	25	< 0.1
401	Soil	0.10	0.45	Late	25	< 0.1
402	Soil	0.02	0.09	Late	25	< 0.1
403	Soil	0.02	0.09	Late	25	< 0.1
404	Overhead	0.10	0.45	Early	25	< 0.1
405	Overhead	0.10	0.45	Early	25	< 0.1
406	Overhead	0.10	0.45	Early	25	< 0.1
407	Overhead	0.10	0.45	Late	25	< 0.1
408	Overhead	0.10	0.45	Late	25	< 0.1
409	Overhead	0.02	0.09	Late	25	< 0.1
Control	--	--	--	--	25	< 0.1

Table E6
Diquat Residues in Carrots

Sample No.	Type of Irrigation	Diquat Application Rate		Stage of Maturity of Crop at Time of Application	Weight of Carrots Harvested g	Weight of Sample Analyzed g	Diquat* Concentration ppm
		lb/acre	Concentration in 1-acre-in. H ₂ O, ppm				
377	Overhead	0.02	0.09	Early	387	125	< 0.05
378	Overhead	0.02	0.09	Early	407	125	< 0.05
389	Overhead	0.02	0.09	Early	279	125	< 0.05
380	Overhead	0.02	0.09	Early	362	125	< 0.05
381	Overhead	0.1	0.45	Late	456	125	< 0.05
382	Overhead	0.1	0.45	Late	396	125	< 0.05
383	Overhead	0.1	0.45	Late	529	125	< 0.05
384	Overhead	0.5	2.25	Late	509	125	< 0.05
385	Overhead	0.5	2.25	Late	314	125	< 0.05
386	Overhead	0.5	2.25	Late	590	125	< 0.05
387	Overhead	0.5	2.25	Late	471	125	< 0.05
388	Soil	0.5	2.25	Late	321	125	< 0.05
389	Soil	0.5	2.25	Late	518	125	< 0.05
390	Soil	0.5	2.25	Late	301	125	< 0.05
391	Soil	0.5	2.25	Late	469	125	< 0.05
Control	--	--	--	--	175	125	< 0.05
Control	--	--	--	--	244	125	< 0.05

* Practical limit of detection was 0.05 ppm of diquat.

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Table E7
Diquat Residues in Lettuce

Sample No.	Type of Irrigation	Diquat Application Rate		Stage of Maturity of Crop at Time of Application	Weight of Lettuce Harvested g	Weight of Sample Analyzed g	Diquat* Concentration ppm
		lb/acre	Concentration in 1-acre-in. H ₂ O, ppm				
352	Soil	0.02	0.09	Late	455	125	< 0.05
353	Soil	0.02	0.09	Late	476	125	< 0.05
354	Soil	0.02	0.09	Late	369	125	< 0.05
355	Overhead	0.02	0.09	Late	532	125	< 0.05
356	Overhead	0.02	0.09	Late	379	125	< 0.05
357	Overhead	0.02	0.09	Late	264	125	< 0.05
358	Overhead	0.02	0.09	Late	590	125	< 0.05
359	Soil	0.10	0.45	Late	543	125	< 0.05
360	Soil	0.10	0.45	Late	465	125	< 0.05
361	Soil	0.10	0.45	Late	503	125	< 0.05
Control	--	--	--	--	512	125	< 0.05
392	Overhead	0.10	0.45	Late	414	125	< 0.10
393	Overhead	0.10	0.45	Late	468	125	< 0.05
394	Overhead	0.10	0.45	Late	436	125	< 0.05
395	Overhead	0.10	0.45	Late	411	125	0.10
396	Soil	0.10	0.45	Late	415	125	< 0.05

* Practical limit of detection is 0.05 ppm of diquat.

Table E8

Diquat Residues in Onion Bulbs

Sample No.	Type of Irrigation	Diquat Application Rate		Stage of Maturity of Crop at Time of Application	Weight of Onions Harvested g	Weight of Sample Analyzed g	Diquat* Concentration ppm
		lb/acre	Concentration in 1-acre-in. H ₂ O, ppm				
362	Soil	0.5	2.25	Late	246	125	< 0.05
363	Soil	0.5	2.25	Late	249	125	< 0.05
364	Soil	0.5	2.25	Late	302	125	< 0.05
365	Soil	0.5	2.25	Late	271	125	< 0.05
366	Overhead	0.5	2.25	Late	331	125	< 0.05
367	Overhead	0.5	2.25	Late	279	125	< 0.05
368	Overhead	0.5	2.25	Late	432	125	< 0.05
369	Overhead	0.5	2.25	Late	290	125	< 0.05
370	Soil	0.1	0.45	Late	361	125	< 0.05
371	Soil	0.1	0.45	Late	332	125	< 0.05
372	Soil	0.1	0.45	Late	328	125	< 0.05
373	Overhead	0.1	0.45	Late	280	125	< 0.05
374	Overhead	0.1	0.45	Late	330	125	< 0.05
375	Overhead	0.1	0.45	Late	267	125	< 0.05
376	Overhead	0.1	0.45	Late	193	125	< 0.05
Control	--	--	--	--	--	125	< 0.05
Control	--	--	--	--	--	125	< 0.05

* Practical limit of detection is 0.05 ppm of diquat.

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APPENDIX F

FINAL ENVIRONMENTAL STATEMENT FOR WALKER DAM
IMPOUNDMENT, AQUATIC PLANT CONTROL PROJECT,
NEW KENT COUNTY, VIRGINIA

Prepared by the

U. S. ARMY ENGINEER DISTRICT, NORFOLK, VIRGINIA

and the

VIRGINIA COMMISSION OF GAME AND INLAND
FISHERIES, RICHMOND, VIRGINIA

15 May 1972

FINAL ENVIRONMENTAL STATEMENT FOR WALKER DAM
IMPOUNDMENT, AQUATIC PLANT CONTROL PROJECT,
NEW KENT COUNTY, VIRGINIA

Included herein (Inclosure 1) is the Final Environmental Statement for Walker Dam Impoundment, Aquatic Plant Control Project, New Kent County, Virginia.

Walker Dam Impoundment
Aquatic Plant Control Project
New Kent County
Virginia

() Draft (X) Final Environmental Statement

Responsible Office: U. S. Army Engineer District, Norfolk, Virginia

1. Name of Action: (X) Administrative () Legislative
2. Description of Action: Initiate program in conjunction with the State, designed to control infestation of egeria (Egeria densa) through chemical treatment with a 50-50 mixture of herbicide diquat dibromide and potassium endothall.
3. a. Environmental Impacts: The control of egeria would increase recreational activity, insure adequate water velocities for intake systems and increase fish production on the reservoir.

b. Adverse Environmental Effects: Minor fish kills, reduction in available dissolved oxygen associated with bacterial oxidation of dead plants, rendering of reservoir water unsuitable for drinking purposes for approximately two weeks, potential damage to a tree farm near upper reaches of lake.
4. Alternatives: "No-improvement," alteration of lake habitat through water level reduction, mechanical control of aquatic vegetation, and removal of nutrient sources.
5. Comments received:

Virginia Institute of Marine Science
Bureau of Outdoor Recreation, U.S. Department of Interior
Agricultural Research Service, U. S. Department of Agriculture
Environmental Protection Agency
Conservation Council of Virginia, Inc.
Virginia State Water Control Board
National Marine Fisheries Service, U. S. Department of Commerce
6. Draft Statement to CEQ: 28 March 1972.

Final Statement to CEQ: 18 OCT 1972 .

WALKER DAM IMPOUNDMENT
AQUATIC PLANT CONTROL PROJECT

ENVIRONMENTAL STATEMENT

1. Project description. The Walker Dam Impoundment Aquatic Plant Control Project was authorized by Section 302 of the River and Harbor Act of 1965 (Public Law 89-298, 89th Congress). The proposed project is designed to control, on a single application only basis, the profuse infestation of egeria (*Egeria densa*) through chemical treatment with a 50-50 mixture of diquat dibromide and potassium endothall. The most recent economic analysis (May 1969) indicates a benefit-cost ratio of 2.9 to 1.0.

The method to be employed to eradicate the plant infestation is to treat the entire 1,100-acre impoundment, the chemicals being sprayed into the water with the aid of an airboat. The chemical formulation chosen (diquat-endothall) has been found in the past to provide successful results on the reservoir when applied at the rate of 1.5 gallons per surface acre. Application of the chemical mixture in the vicinity of the tree farm located near the upper reaches of the lake will be carefully regulated and controlled so as not to contaminate water intake systems used for irrigation. The water in the reservoir will be tested prior to resumption of its use for domestic purposes.

2. Environmental setting without the project. The Walker Dam Impoundment is a tidal barrier dam located 30 miles southeast of Richmond, Virginia on the Chickahominy River (Exhibits 1 and 2). The dam was constructed in 1943 as a war emergency measure. Today, water provided by the reservoir is piped to the nearby cities of Williamsburg and Newport News, Virginia. The reservoir covers an area of 1,100-acres. Maximum dam height is approximately 3 feet above the normal maximum tide level. The mean tide range is between 2.5 and 3.0 feet. Extreme high tides from hurricanes or other unusual weather conditions occasionally overlap the tidal barrier.

The Chickahominy River, a tributary of the James River, follows a winding southeasterly path before converging with the James approximately 15 miles west of Williamsburg, Virginia. Prior to dam construction, the Chickahominy River was navigable in the area inundated by Walker Dam. Navigability is maintained by a small boat lock which was installed in the face of the dam.

Chickahominy Reservoir is situated in a rural area consisting of low-lying marshland, most of which is below elevation 10 feet, m.s.l. Walkers, a small rural settlement having a population of about 15, is

located on the Chickahominy. The nature of the land surrounding the reservoir does not lend itself to widespread agricultural usage. No major industries are associated with the reservoir other than a tree farm maintained by the State.

Aside from its principal service as a portion of the water supply for the cities of Newport News and Williamsburg, Chickahominy Reservoir is noted for its fishery. The shallow, enriched, and weed-covered waters provide excellent habitat for largemouth bass, pickerel and bluegill. Crappie, flier, bowfin, and other species also inhabit the reservoir in good numbers. Surrounding marshes provide private and commercially guided duck-hunting opportunity in fall and winter months. Five separate private fishing marinas and duck-hunting camps, as well as numerous cottages, cover and control most of the northern shoreline of Chickahominy Reservoir. The State Forestry Department of Virginia maintains a tree farm near the upper end of the reservoir. Nearly all of the southern shoreline is in private ownership as timber tracts, private duck marshes or summer cabins. One youth camp is also located along the southern shoreline near Walker Dam.

The primary purpose of Chickahominy Reservoir is now in jeopardy (that of supplying water for domestic purposes), as are associated recreational activities. Based on information concerning the rate at which the reservoir surface is being reduced by filling (approximately 200 surface acres in 25 years), and on acreage of the original stream channel (around 184 acres), it is predicted that in another 115 years only the stream channel will remain. Long before that time, use of the reservoir as a functional unit will be lost. Fishing and boating waters are not only declining rapidly because of surface area reduction, but rooted aquatic weeds now restrict the use of much of the reservoir during spring, summer, and fall months. The declining storage capacity and recreational potential contrast sharply with water and recreational needs of Newport News and the surrounding region.

Reasons for the rapid decline in storage capacity and in the restriction of recreational activities are severalfold. A major problem is the profuse infestation of rooted aquatic weeds which provide a constantly increasing accumulation of plant material and which tend to entrap silt in increasing quantities. Shallow areas result. As eutrophication continues, shallow areas are invaded by typical marshland vegetation and the shallows become intermittently wetted marshes. Large quantities of nitrogen, phosphorus, carbon and other plant nutrients being supplied from upstream sources compound problems by creating ideal conditions for the growth of plant life. Nutrient inputs into the Chickahominy drainage from sewage disposal systems have reached such high levels the State Water Control Board has virtually halted further effluent discharges. The problem of egeria establishment in shallow areas is not a direct result of siltation. The Chickahominy Reservoir is a "run of the river" type of impoundment and



(*Egeria* sp.)--found in fresh to slightly alkali inland water and fresh to slightly brackish coastal water.

Common Elodea



Elodea canadensis

it has an exceedingly low dam. Maximum depth of the impoundment at this time is such that egeria can establish at maximum depths unless adequately shaded by phytoplankton populations (maximum depth estimated to under 14 feet).

Sediment movement in Chickahominy River is one of the lowest of any streams of comparable size within Virginia. Major loss of (extremely) shallow areas is due first to establishment of egeria, then to entrapment of any existing sediment, and the accumulation of plant remains followed by encroachment of typical marsh-type plants.

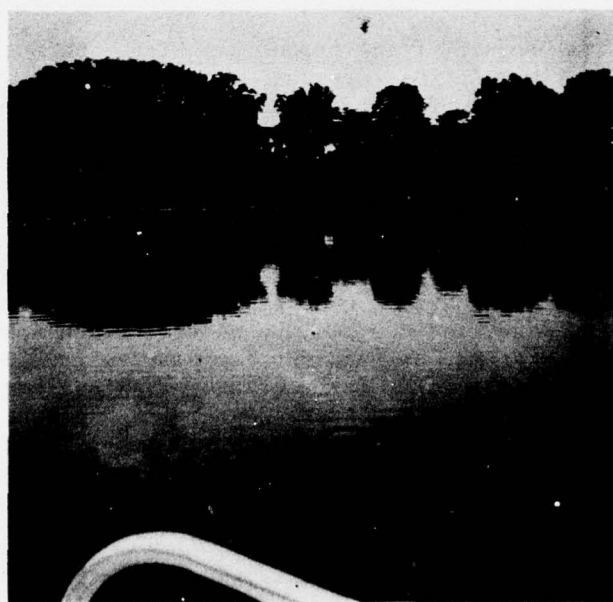
Egeria (Egeria densa), shown on page F7, is the predominant rooted aquatic, although pondweeds (Potamogeton sp.), coontail (Ceratophyllum demersum), and several other rooted aquatic plants are common. Green algae (Pithophora sp.) and duckweed (Lemna sp.) have increased in proportion to rooted aquatics. Shoreline vegetation varies, being composed of rushes, grasses, sedges, watershield (Brasenia schreberi), golden club (Orontium aquaticum), and many other marsh-inhabiting plants including cattails (Typhus sp.), pickerel weed (Pontederia sp.) and yellow waterlily (Nuphar advena). Egeria and elodea were at one time generic synonyms. Egeria is now the accepted common name for what was referred to in the past as Brazilian waterweed.

During the summer of 1967, the Virginia Commission of Game and Inland Fisheries conducted a limited egeria control program (exhibit 3). Strips of the reservoir surface, totaling 200 surface acres were treated with a herbicidal mixture consisting of diquat ([6, 7-dihydrodipyrido (1, 2- α :2', 1'-C) pyrazidiinium dibromide]) and potassium endothall (7-oxabicyclo(2, 2, 1) heptane-2, 3-dicarboxylic acid). Equal portions of the two herbicides were sprayed at an overall rate of 1.5 gallons per surface acre. Treated areas were surveyed during the summers of 1967 and 1968. Chemical treatment was successful in clearing fishing lanes, channels and docksides, as evidenced by the photographs on page F9. Due to erratic chemical drift of the herbicide mixture, the area treated and cleared was found to total approximately 800 surface acres. Field surveys conducted by Commission personnel indicated that the initial 200 acres treated, along with an additional 600 acres, were cleared of egeria by the 34th day after final treatment. The reservoir remained relatively free of egeria during 1968 and 1969. However, because live strands of egeria remained near the periphery of the treated areas and in unaffected portions of the reservoir, vegetation returned to former levels of abundance.

Longevity of the partial egeria treatment was substantially longer than anticipated. Relatively large quantities of nitrate, phosphate,



Before Treatment



After Treatment

Chickahominy Reservoir

carbon, and other nutrients enter the reservoir from the Chickahominy River. The nutrients are supplied by upstream sewage disposal plants and by the swampy lands through which the Chickahominy River flows. A majority of the nutrients were utilized by rooted plants prior to herbicide application, especially egeria, while phytoplankton populations were minimal. Conditions reversed following treatment. Desirable phytoplankton increased markedly and light levels in deeper portions of the reservoir were greatly reduced as a result of shading by phytoplankton. Shading retarded the rate of re-infestation by egeria. Nevertheless, as egeria became more and more plentiful less nutrients were made available to phytoplankton, populations of phytoplankton declined, and the nutrient cycle again reversed. Egeria then spread rapidly into deeper portions of the reservoir.

Diquat dibromide is very soluble in water (70g/100ml@20°C) and forms a very potent translocatable post-emergent herbicide. In neutral solutions the herbicide is very stable, however in alkaline solutions it decomposes forming inactive colored complexes. The herbicide is very rapidly adsorbed and inactivated in the soil hence eliminating possible contamination of any shoreline vegetation. Endothall, though less soluble in water, is a very effective phytotoxic agent which also has been reported to be translocatable. There are three isomers of the compound, the endo-cis isomer having the greatest biological activity. This herbicide is recommended as a pre-emergence plant toxicant. In aqueous systems endothall rapidly decomposes to form ionic metal salts and water and consequently loses its biological effectiveness after 7 days.

3. The environmental impact of the proposed action. Selection of the best herbicides to eliminate the infestation of egeria on the Walker Dam centered around those which biodegrade rapidly, present minimal hazards to humans or other life, are readily accessible in desired quantities, are relatively inexpensive and have been approved for use in potable water supplies.

Registration, the official Federal approval, of herbicides for use in aquatic sites has been a matter of considerable confusion during recent years. As a direct result of this uncertainty, all uses of herbicides are being reevaluated to determine new residue and tolerance criteria in a medium such as water that may be used for human or animal consumption. There exist a number of herbicide formulations which are currently registered for use in aquatic sites and these registered uses are valid until new criteria for registration are developed. The registered uses as listed in Table 1, have limitations against use in water to be used for potable, irrigation, or crop-spraying purposes. According to Gangstad (1),

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- (1) Gangstad, E.O., 1972. Herbicidal control of aquatic plants. Journal of the Sanitary Engineering Division, Proceedings ASCE, SA2, 397-406.

TABLE 1. SELECTED HERBICIDES FOR USE IN WATER (after Gangstad, 1972)

Herbicide name	Dosage rate as active ingredient	Sites, types of weeds and limitations
Ammonium sulfate	57 lb/A-R-171 lb/A	Around lakes, ponds, potable water reservoirs and their supply streams; brush. Do not contaminate water. Lakes, ponds, algae, submersed weeds. Do not apply to water used for domestic purposes. Ditchbanks; weeds, brush control. Do not contaminate domestic water. Lakes, ponds, potable water reservoirs; algae. Drainage ditches, spot treatment; cattails. Lakes, ponds; submersed weeds. Apply to water surface. Do not apply to water used for irrigation or potable purposes. Lakes, ponds ditches, laterals; submersed weeds. Do not use treated water for domestic or irrigation purposes for 10 days. Drainage and irrigation ditches, drain off water, spray moist soil in ditch. Fill ditch and let stand 72 hrs and waste contained water. Do not contaminate domestic water. Ditchbanks, spot treatment, Do not contaminate water used for domestic or irrigation purposes. Lakes and ponds; algae. Do not use treated water within 7 days at 0.3ppm, 14 days at 3.0ppm. Lakes, drainage ditches; submersed weeds. Drain area and apply to exposed bottom. Do not use treated water for domestic purposes. Lakes, ponds; floating weeds. Do not use treated water for domestic or irrigation purposes.
Acrolein	1.2ppm-7.2ppm	
Bromacil	3.0 lb/A-24 lb/A	
Copper sulfate	0.05ppm-2.3ppm(pentahydrate)	
Dalapon	15 lb/A	Lakes, ponds; submersed weeds. Apply to water surface. Do not apply to water used for irrigation or potable purposes. Lakes, ponds ditches, laterals; submersed weeds. Do not use treated water for domestic or irrigation purposes for 10 days. Drainage and irrigation ditches, drain off water, spray moist soil in ditch. Fill ditch and let stand 72 hrs and waste contained water. Do not contaminate domestic water. Ditchbanks, spot treatment, Do not contaminate water used for domestic or irrigation purposes. Lakes and ponds; algae. Do not use treated water within 7 days at 0.3ppm, 14 days at 3.0ppm. Lakes, drainage ditches; submersed weeds. Drain area and apply to exposed bottom. Do not use treated water for domestic purposes. Lakes, ponds; floating weeds. Do not use treated water for domestic or irrigation purposes.
Dichlobenil	10 lb/A-15 lb/A	
Diquat	2 lb cation/A	Lakes, ponds; submersed weeds. Apply to water surface. Do not apply to water used for irrigation or potable purposes. Lakes, ponds ditches, laterals; submersed weeds. Do not use treated water for domestic or irrigation purposes for 10 days. Drainage and irrigation ditches, drain off water, spray moist soil in ditch. Fill ditch and let stand 72 hrs and waste contained water. Do not contaminate domestic water. Ditchbanks, spot treatment, Do not contaminate water used for domestic or irrigation purposes. Lakes and ponds; algae. Do not use treated water within 7 days at 0.3ppm, 14 days at 3.0ppm. Lakes, drainage ditches; submersed weeds. Drain area and apply to exposed bottom. Do not use treated water for domestic purposes. Lakes, ponds; floating weeds. Do not use treated water for domestic or irrigation purposes.
Diuron	32 lb/A-80 lb/A	
DMSA	2.3 lb/A-4.5 lb/A	Lakes, ponds; submersed weeds. Apply to water surface. Do not apply to water used for irrigation or potable purposes. Lakes, ponds ditches, laterals; submersed weeds. Do not use treated water for domestic or irrigation purposes for 10 days. Drainage and irrigation ditches, drain off water, spray moist soil in ditch. Fill ditch and let stand 72 hrs and waste contained water. Do not contaminate domestic water. Ditchbanks, spot treatment, Do not contaminate water used for domestic or irrigation purposes. Lakes and ponds; algae. Do not use treated water within 7 days at 0.3ppm, 14 days at 3.0ppm. Lakes, drainage ditches; submersed weeds. Drain area and apply to exposed bottom. Do not use treated water for domestic purposes. Lakes, ponds; floating weeds. Do not use treated water for domestic or irrigation purposes.
Endothal	0.05ppm-0.83ppm	
Fenac	15 lb/A-20 lb/A	
2,4-D	2.4 lb/A	

these limitations leave unanswered how such waters can be treated to control weeds, and may be impracticable because the use to which water may be put is not necessarily defined by the name of the aquatic site. He further is of the opinion that the limitation that treated water should not be used for domestic, spraying, or irrigation purposes may be unrealistic for two reasons: (1) water flows to new sites and may not be recognized as treated water in the new site, and (2) the caution gives no duration or time limit to the prohibition against use, meaning presumably that treated water may never be used again. It is assumed that this limitation is based on lack of information on the actual concentration of the herbicides in treated water, and the lack of information on its rate of breakdown or degradation and other forms of its removal from the water.

There exists the possibility that the lake may become infested with blue-green algae if the aquatic plants are destroyed and the sources of nutrients are not removed. Similar patterns have been documented in Lake Zoar, Connecticut and in the tidal freshwater Potomac River. The possibility exists that blue-green algae could present a tremendous management problem for taste and odor control in water supplies. Surveys made by the Virginia Commission of Game and Inland Fisheries in years following the previous egeria control (by herbicidal action) did not indicate blue-green algae were or would become a problem in the lake. Lake Zoar, Connecticut and the freshwater Potomac River are not dark stained coastal plains waters. The findings as cited by the Environmental Protection Agency, provide a questionable insight into Chickahominy Reservoir conditions and they do not conform with previously observed conditions. The spraying program, as described, is not designed to completely remove all aquatic plants from the reservoir, or even all the egeria. A single herbicide application in conjunction with more stringent nutrient control should reduce the aquatic plant infestation to a manageable level, a level which would leave enough plants to absorb incoming nutrients that could otherwise be absorbed by blue-green algae.

Current pollution control and abatement plans for the Chickahominy Watershed, as developed by the State Water Control Board, will be sought from this source. Nevertheless, upstream conditions are such that adequate control of conditions in the reasonable future do not seem problematical.

The proposed chemical treatment will render water in the reservoir unsuitable for domestic purposes for a period of approximately two weeks. During the 1967 chemical treatment, the cities of Williamsburg and Newport News agreed to curtail their use of reservoir waters for a period of 7 days following treatment.

Even though the waters of the Chickahominy Reservoir are used for potable consumption, pumping would not take place following treatment until herbicides are undetectable, as determined by a water testing program. Water pumped from Chickahominy Reservoir does not go directly into water mains but in turn is pumped to and discharged into Lee Hall Reservoir. Lee Hall Reservoir has a surface acreage of approximately 300 surface acres. Even if water were pumped from Chickahominy Reservoir directly after treatment, it is questionable if herbicides would persist till the time the waters passed through Lee Hall Reservoir and into charcoal filters of the Newport News central water distribution station. This is a secondary built-in safeguard.

Literature reviews by Commission Biologist indicate that application levels well above the proposed rate of 1.5 gallons per surface acre would be required before herbicide concentrations became lethal for fish life. Diquat has been shown to have an acute oral LD₅₀ rate of 400-440 mg/kg for rats while endothall has an acute oral LD₅₀ of 35 mg/kg of body weight for rats. Presumably, both diquat and endothall have relatively low toxicities for both fish and mammals. Few fish kills were associated with the initial 200-acre treatment of the reservoir. Fish mortalities were attributed to an oxygen depletion caused by the rapid decomposition of the dead egeria and not necessarily to introduction of the chemical mixture.

Removal of fish from Chickahominy Reservoir would be restricted for a suitable time following treatment. Spraying would be in accord with previous application measures (exhibit 3), which harmed no terrestrial vegetation. Herbicide mixture is sprayed at approximately one foot above the water surface. Treatment measures used previously, as documented by field investigations, caused only minor fish kills.

Fish kills, as mentioned above, were attributed to oxygen depletion and not the herbicides. Furthermore, areas where kills occurred were confined to isolated guts that probably could not be treated in a manner that would not produce some fish loss.

For a spraying program to be effective on Chickahominy Reservoir, application of herbicides must be conducted within a very narrow time frame. Commission Biologists are of the opinion that best results could be obtained if the reservoir were treated in early June, or no later than the first of July. Aquatic plants would be most susceptible to chemical treatment at this time for the following reasons: (1) it is early in the growing season and before the maximum quantity of plant material is present, (2) the water temperature in the reservoir is not high, and (3) excessive anaerobic conditions could be minimized, consequently preventing severe fish losses.

From results of previous egeria control work at Chickahominy Reservoir, Virginia Commission of Game and Inland Fisheries biologists have agreed that both herbicides when applied simultaneously will provide excellent results. It appears that the two chemicals act synergistically when combined in a 50:50 ratio. The recommended prices ^{1/} of diquat and potassium endothall are \$32.50/gallon and \$16.00/gallon, respectively. Cost relationships between the two chemicals allow a larger area to be treated than if diquat alone was used, at a reduced cost/acre factor.

4. Any adverse environmental effects which cannot be avoided should the proposal be implemented. Implementation of the proposed action will probably affect the entire 1,100 acres inundated by the reservoir. Chemical treatment of the entire 1,100 acres may present some adverse effects on associated fish and wildlife forms. The initial aquatic plant control project was designed to spray approximately 200 acres of the impoundment. Erratic wind and wave conditions caused the herbicides to diffuse at a greater rate than previously anticipated. As a result, approximately 800 acres of the impoundment were effectively treated with diquat and potassium endothall. This treatment represented approximately 73% of the reservoir. If the entire reservoir area is treated, excluding the duck-hunting marshes, some minor fish kills can be expected as a result of plant decomposition and an accompanying oxygen drawdown. It is debatable whether any mammals or reptiles associated with the reservoir would be killed unless actual concentrations of the herbicides were significantly increased.

A second effect of the chemical treatment is potential damage to the tree farm located near the upper reaches of the lake. Irrigation of the forest nursery with lake waters would have to be suspended until toxicity of the herbicides has decreased to an approved level. This problem could be eliminated if the spraying operation purposely avoided the extreme upper reaches of the lake.

There is little likelihood of injury to the forest nursery plantings since the influx of water from the river should serve to clear this area of herbicide residues first. If use of the water from this point is postponed for several days, no problems should arise.

A third effect which may be associated with the proposed herbicide treatment is the potential downstream contamination associated with an overlap of the dam by wave action. Possible damage to the downstream fauna and flora could then result; however, this condition would only occur as a result of the high tides generated by a hurricane or some other atypical weather condition. In addition, the flow past the dam at this time of year is either non-existent or very low and any downstream contamination would be highly unlikely.

^{1/} 1967 suggested retail price lists - Virginia.

Fourthly, contamination of drinking water is possible if water is pumped from the reservoir before biodegradation of the two herbicides is complete. Literature reviews have indicated both potassium endothall and diquat biodegrade in 14 days or less. No problems were encountered when the chemicals were used previously. However, it is proposed that waters in the vicinity of the existing pumping station, and at selected intervals in the reservoir, be tested for the presence of both chemicals prior to resumption of water supply pumping. Under these conditions, actual contamination of water supplies would be remote.

The Virginia Commission of Game and Inland Fisheries, with the concurrence of the Virginia Department of Health and the cities of Williamsburg and Newport News, reported that the chemical treatment of the reservoir was relatively successful in light of the other means by which the plant growth could have been controlled.

An additional adverse effect would be the possible loss of food for wildfowl by the elimination of pondweeds. This loss would be most severe during the first year but, in years to come with the elimination of egeria, the pondweeds would be able to reestablish and be more prolific than before treatment. As a result, wildfowl food supplies would be partially enhanced.

5. Alternatives to the proposed action. The first alternative would be to forego the improvement of this reservoir and preserve the present environmental setting of Walker Dam. State and local interests are unanimously in favor of the proposed project since the improvement of the reservoir would be viewed as an economic asset to all who live in the area, to those who depend on the reservoir for at least a partial livelihood and to those who use the reservoir for recreational purposes. Since there has been no objection to the proposed action, there is no reason to consider the "no-improvement" alternative.

A second alternative would be to alter the reservoir habitat in such a way as to deter the yearly growth of the waterweeds. This could be accomplished either through water level reduction or upstream removal of nitrate and phosphate sources.

Water level reduction, followed by an interval of exposure to freezing weather may provide long-lasting control of aquatic vegetation. This means of modifying habitat could result in complete elimination of weed growths. Coordinated flushing actions also would help to reduce the accumulation of silt and humic material in the reservoir. Control of this type can be regarded as permanent, although annual "drawdown" would be required. Unfortunately, no means exist for rapid flushing of Chickahominy Lake, and long

term water level reductions would present problems. According to the Department of Public Utilities, city of Newport News:

"Lowering the level of the lake is both impracticable and undesirable from the city's point of view. First, it is not practicable to lower the water through the locks and the only other opening is the ladder which provides too small an area. Secondly, it is not in the best interest of the city to lower the level of the lake, since the water may be needed, particularly in the summer."

Annual exposure of shallows to freezing and dessication, when coupled with flushing actions, if feasible, undoubtedly would be the least expensive long term, permanent solution for the control of any rooted aquatic growths in Chickahominy Reservoir. However, manipulation of the reservoir's water level is not recommended for the following reasons:

a. The dam is old and would require extensive remodeling, if not replacement, in order to install a new system of gates.

b. The dam is located in tidal waters and the elevation of the water in the impoundment is about three feet above maximum normal tide level below the dam. The mean tidal range of the river below the dam is between 2.5 and 3.0 feet. During high tides and storms, there is actually an intrusive flow of downstream salt water into the freshwater impoundment. The slight difference in water levels could make successful lowering of the impoundment, to any extent, an impossibility.

c. Since egeria grows to a depth of about 10 feet and the depth of the impoundment in most areas is less than this figure, it would be necessary to virtually "dry-up" the reservoir to obtain any appreciable bottom dessication or root freezing.

d. Normal daily summer pumping rate for Chickahominy Reservoir is approximately 22,000,000 gallons. If the level of the reservoir were lowered in winter and not refilled by the following summer dangerously low water supplies would result.

While the reduction of and phosphates entering Chickahominy Reservoir from upstream sources is perhaps a logical course of action it (a) cannot be accomplished without a considerable time lag (figured in years) (b) is mainly under the jurisdiction of the State Water Control Board and not that of the Army Corps of Engineers or the Virginia Commission of Game and Inland Fisheries and, (c) if nitrates and phosphates were channeled into phytoplankton rather than into rooted aquatics the existing levels would be

desirable from a fisheries standpoint. Herbicidal control, while providing a temporary effect, would still give a substantial number of years relief from the rooted aquatic problem. By the time rooted aquatics could again reach nuisance levels, conceivably, the State Water Control Board might have achieved a reduction in nitrate and phosphate levels. However, weed problems exist and persist in surrounding watersheds which are not receiving sewage discharges. This indicates natural phosphate and nitrate levels may be high enough to maintain existing weed populations, though perhaps at somewhat lower levels. Past evidence has indicated that recycling nutrients into desirable phyto-plankton populations would not take place without herbicidal, physical or biological control of the rooted aquatics.

A third alternative which could be employed to control aquatic vegetation involves the use of mechanical devices to harvest weed growth. The regenerative capacity of subdivided fragments of egeria would require the mechanical harvester to not only sever the plant, but also collect all fragments. Incomplete removal of plant fragments would allow conditions prior to treatment to be quickly restored.

A recent field inspection of several mechanical cutters and harvesters revealed that most cutters adequately cut aquatic plants, but at the same time they leave a substantial amount of plant fragments unharvested. This floating material can quickly re-establish itself, reinfest controlled regions and spread to other areas. Thus, it can be assumed that any use of mechanical cutters and harvesters would intensify the present aquatic plant problem, rather than relieve it.

6. The relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity. The long-term productivity of Chickahominy Reservoir will be affected insofar as one or more of the natural components of the ecosystem will be eliminated or greatly reduced, namely egeria and associated troublesome plant life. It is possible that if complete chemical treatment of the reservoir is carried out, egeria and other rooted aquatics will be reduced to the point where inflowing nutrients are cycled through the highly desirable phyto-plankton chain for many years before a reversal of the cycle again takes place. Even if this end could not be fully accomplished, removal of egeria and other infesting rooted aquatics should directly increase longevity and ultimately productivity of the system by increasing the useful life of the reservoir. Were nutrients to be cycled over a long span primarily through phyto-plankton instead of rooted plants, life span and productivity of the reservoir would be extended greatly.

7. Any irreversible or irretrievable commitment of resources which would be involved in the proposed action should it be implemented. Implementation of this project is not thought to bring about any irreversible or irretrievable

commitment of resources. This is largely due to the uniqueness of the proposed project since no marshes are being filled with spoil, no land is being inundated by water and no channels are being dredged. Each of the above actions typically involve some type of resource commitment. The only anticipated impact lies in modification of the aquatic ecosystem, an alteration which will be temporary and nondestructive in its effects.

8. Coordination with others.

a. Public Participation. A news release was issued stating that the draft environmental statement had been prepared and was available from the District Engineer. A public meeting was not held since there were no known unresolved conflicts.

b. Government and State agencies. The draft environmental statement was sent to the following agencies requesting their views and comments. These comments are summarized below and copies of the replies are attached to the environmental statement.

(1) VIRGINIA INSTITUTE OF MARINE SCIENCE.

Comment: If control is attained substantial benefits will result.

Comment: No release of the lake water should be made to the Chickahominy River while the herbicide is still active.

Response: The spraying program would only be conducted at a time of the year when the water level in the dam is low due to low rainfall and high evaporation. The volume of water flowing past the dam is below average during the month of June. Damage to downstream shoreline vegetation is not expected for two reasons (1) low flow rates and (2) existing vegetation is very hardy and would be resistant to herbicidal action.

(2) AGRICULTURAL RESEARCH SERVICE, USDA.

Comment: The data presented make it appear unlikely that any permanent or long-term deleterious effect will occur as a result of this program.

Comment: Suggested the water be tested for the presence of herbicides prior to resumption of its use for domestic purposes.

Response: This statement is considered valid and a testing program is treated in the "Impact Section" of the statement.

Comment: If the entire reservoir is to be treated at one time, then it should be done before the maximum quantity of plant material is present, and before the water temperature becomes high.

Response: The spraying program, as described, would be most effective if conducted during the month of June. This is further discussed in section 3 of the impact statement.

Comment: Did not concur that endothall is effective on egeria nor that a rather long exposure time is required.

Response: While endothall is not specifically effective on egeria, as suggested on page 8, inclosure 1, when used in equal ratio with other herbicides such as silvex or diquat it tends to act synergistically on both egeria and several other aquatics such as duckweed, pondweeds, and coontail, all of which are present on the Chickahominy Reservoir. The statement has been revised to include this comment.

Comment: There is a potential loss of wildfowl food by the destruction of some species such as pondweeds.

Response: The comment was considered valid and incorporated into the statement.

Comment: The Weed Science Society of America now recognizes Egeria densa Planch as the correct Latin name and egeria as the common name for what was frequently referred to in the past as Brazilian waterweed.

Response: The comment was considered valid and standardized generic and common names have been revised in the statement.

(3) BUREAU OF OUTDOOR RECREATION, USDI.

Comment: The draft appears to objectively discuss the impact of the proposed action and based on the information contained in the statement would not have a significant effect on those areas of our responsibility.

(4) U.S. ENVIRONMENTAL PROTECTION AGENCY.

Comment: The most logical course of action would be that of reducing the amount of nitrates and phosphates entering the reservoir.

Response: The alternative section of the statement was modified to include this comment, even though this method of plant control would provide no immediate solution to the problem.

Comment: Destruction of aquatic plants without removing nutrient sources may allow the lake to become infested with blue-green algae.

Response: This comment was considered valid and section 3 of the statement has been rewritten to clarify this point.

Comment: A concerted soil erosion program should be established in the Chickahominy River Watershed to control siltation.

Response: This comment was considered and the inability to control or remove aquatic plants by this method alone is treated in section 2 of the impact statement.

Comment: Neither diquat nor endothall are registered for use in potable water.

Response: This comment was not considered to be valid, reasons being discussed in the "impact" section of the present statement.

(6) VIRGINIA STATE WATER CONTROL BOARD.

Comment: The chemicals to be used, as described in the statement, apparently will not cause any long-term dangers.

Comment: The Board's policy statement prohibits their approval of the spraying program, however, the project could be implemented providing an agreement can be reached on discontinuing the use of the impoundment waters for domestic purposes while the herbicides are detectable.

Response: This comment was considered valid and the discontinuation of pumping to the cities of Newport News and Williamsburg would be coordinated with these cities before the program was initiated. In addition, a herbicide level surveillance program is to be conducted by the State.

Comment: It was felt that the lake should be closed to fishing and other recreational uses for at least a week following treatment. The waters of the lake should likewise not be used for irrigation during this period.

Response: All recreational and domestic uses of the reservoir, as well as crop irrigation uses, will be suspended for at least 10-14 days following treatment of the reservoir. By this time the waters of the reservoir should be safe for the above-mentioned uses. The absence of the herbicides will be confirmed by the surveillance methods described.

(7) NATIONAL MARINE FISHERIES SERVICE, USDC.

Comment: The environmental statement provided both a good project description and adequately addresses major environmental topics.

Comment: The statement recognizes the basic factors responsible for the egeria problem and the efforts to deal with root causes are commendable.

(8) U. S. BUREAU OF SPORT FISHERIES & WILDLIFE.

No comments received.

(9) U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE.

No comments received.

(10) NATIONAL PARK SERVICE.

No comments received.

(11) VIRGINIA DIVISION OF WATER RESOURCES.

No Comments received.

(12) VIRGINIA COMMISSION OF OUTDOOR RECREATION.

No comments received.

(13) GOVERNOR'S ENVIRONMENTAL COUNCIL.

No comments received.

(14) CITY OF WILLIAMSBURG, VIRGINIA.

No comments received.

(15) CITY OF NEWPORT NEWS, VIRGINIA.

No comments received.

c.. Citizens group.

CONSERVATION COUNCIL OF VIRGINIA, INC.

Comment: The project appears to us to have been carefully thought out, and we doubt that any harm will result from the proposal.

10 Exhibits

1. Location Map, Chickahominy River, Va.,
Walker Dam Impoundment, Jan 72
2. Map, Aquatic Plant Problem, Chickahominy River,
Va., Walker Dam Impoundment, Jan 72
3. Article "Elodea Control in a Potable Water Supply
Reservoir", from Hyacinth Control Journal, Vol 8,
May 1969
4. Letter from Virginia Institute of Marine Science, 18 Feb 72
5. Letter from U. S. Department of Agriculture, 16 Mar 72
6. Letter from Bureau of Outdoor Recreation, 17 Mar 72
7. Letter from Environmental Protection Agency, 5 Apr 72
8. Letter from Virginia State Water Control Board, 9 May 72
9. Letter from National Marine Fisheries, 8 May 72
10. Letter from Conservation Council of Virginia, Inc., 27 Mar 72

Norfolk District, Corps of Engineers
Norfolk, Virginia 23510

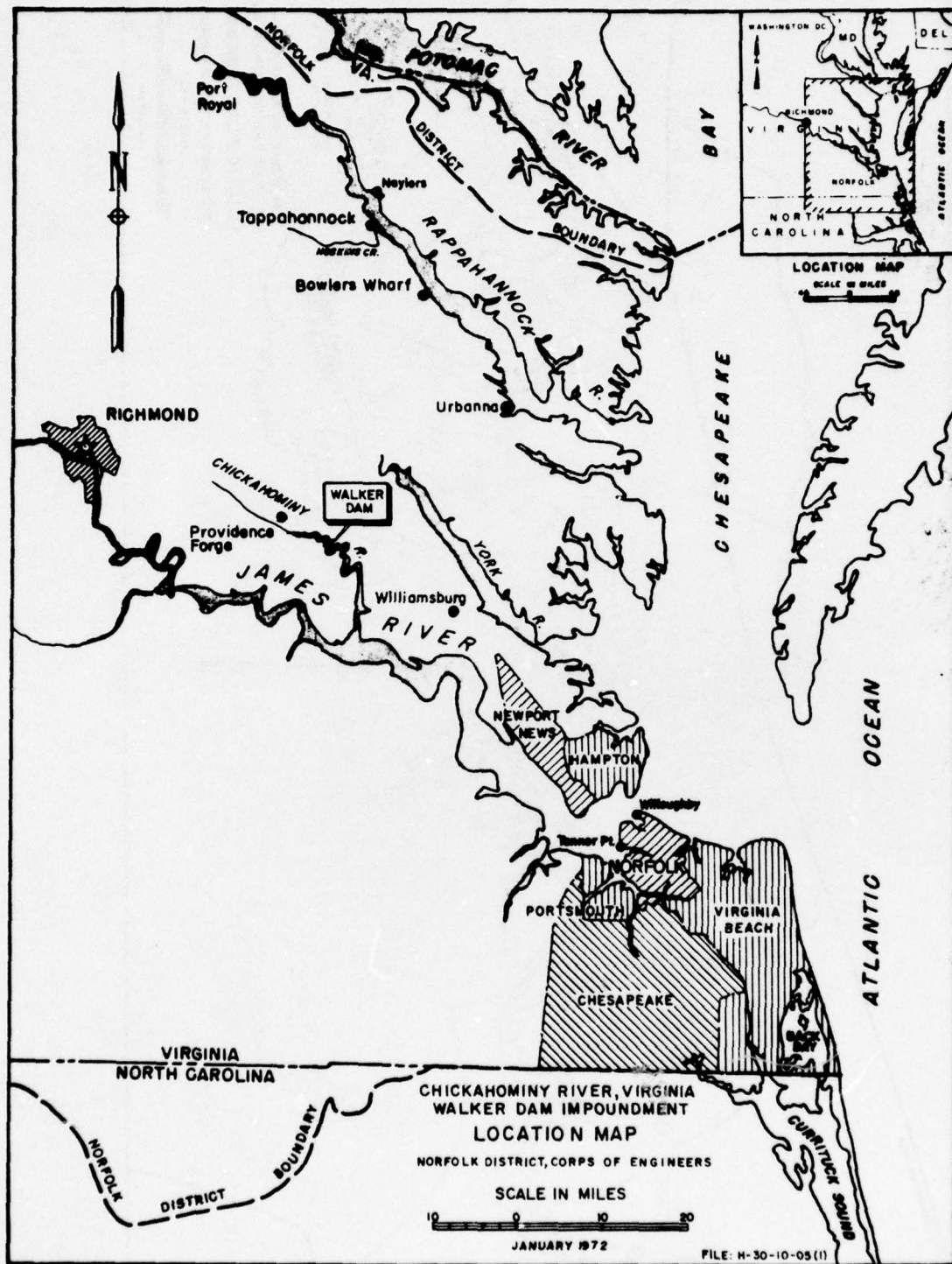
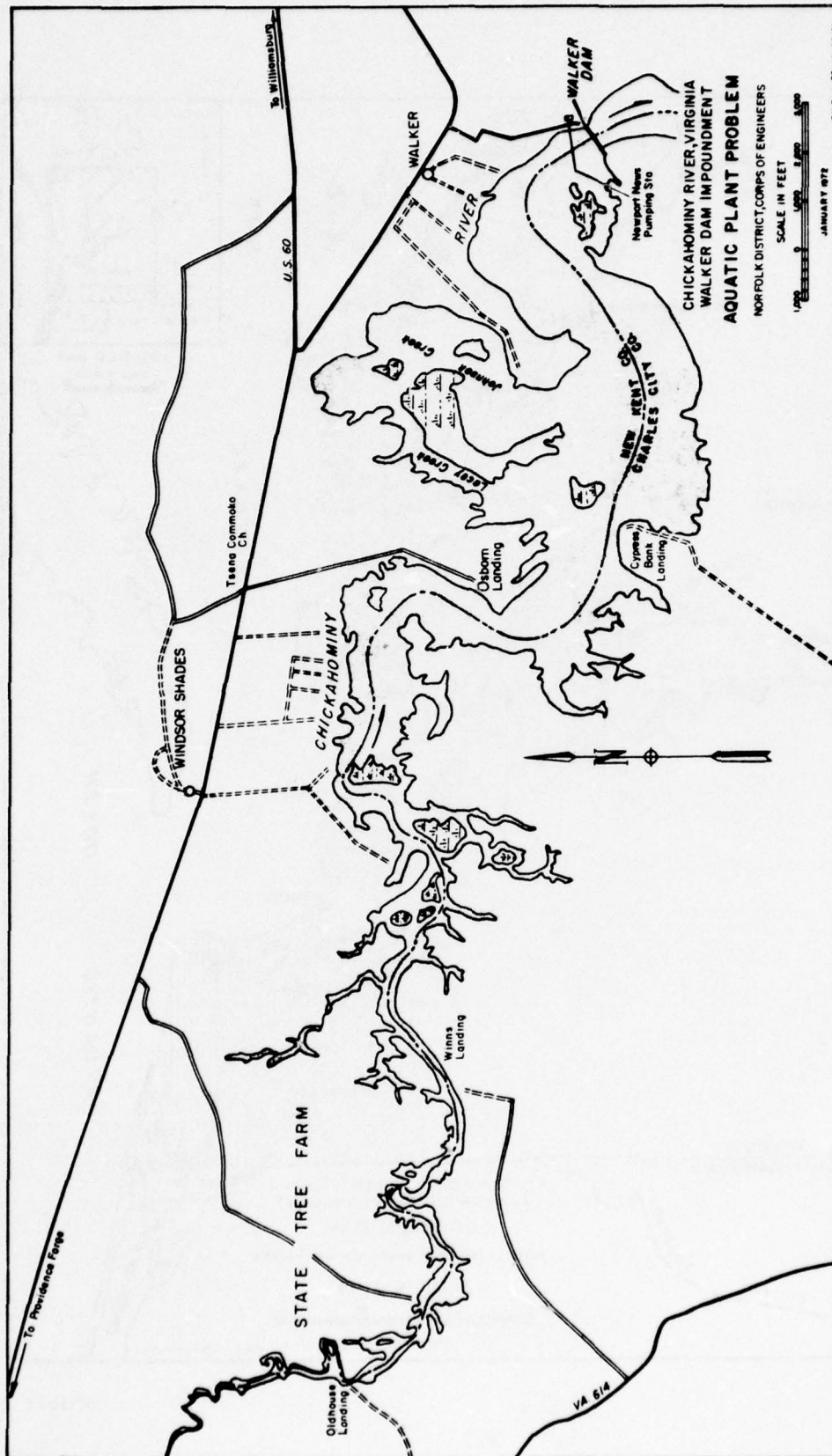


Exhibit 1



Elodea Control In A Potable Water Supply Reservoir

RAYMOND V. CORNING

Supervising Fish Biologist
and

NORVILLE S. PROSSER

District Fish Biologist
Virginia Commission of Game & Inland Fisheries

INTRODUCTION

Population expansion in the upper reaches of the Chickahominy River drainage (located in the lowlands of Virginia) has been rapid during the past 10 years. Recent water pollution studies have indicated a high nutrient enrichment of Chickahominy River waters entering Chickahominy Reservoir (via sewage treatment facilities) is one of the outcomes of this population explosion (10). Another outcome has been the heavy demands placed upon available recreational facilities.

Waters of 1,100 surface acre Chickahominy Reservoir provide a source for potable water for the cities of Newport News and Williamsburg, Virginia. The reservoir also provides a source of much needed fishing recreation. Chickahominy Reservoir is essentially a run of the river impoundment flooding terraces on each side of the river bank to depths of only a few feet. The major reason for the dam was to prevent mixing of saltwater from downstream sources with upstream water that was suitable for drinking purposes. Over the years and despite marked increases in fishermen visits, the nutrient enriched waters have gained a reputation for producing "lunker" sized bass (*Micropterus salmoides* (Lacepede)), bluegill (*Lepomis macrochirus* Rafinesque), black crappie (*Pomoxis nigromaculatus* (LeSueur)), chain pickerel (*Esox niger* LeSueur), and channel catfish (*Ictalurus punctatus* (Rafinesque)).

Unfortunately, Brazilian waterweed or elodea (*Egeria densa* (Planch.)) became established in Chickahominy reservoir at an undetermined time in the past. Nearly all portions of the lake less than 12 feet in depth are now infested. The gently inclined shallow waters and above normal water temperatures existing in the flooded reservoir portion lying outside the original stream channel, when coupled with the ready availability of nutrients, created ideal conditions for the growth of aquatic vegetation. Shallow areas are rapidly being filled by humic accumulation provided by the aquatic vegetation, dominantly elodea, and by the entrapment of silt within the vegetation itself. Heavy growths of elodea also prevent motor boat usage on side streams, coves and along shorelines during most of the summer months. Fishing holes free of weeds can seldom be located during summer, even when push poles are used for boat locomotion.

Demands for elodea removal at Chickahominy Reservoir by the fishing public, resort operators, and others, have been voiced for a number of years. The use of the impounded waters for domestic purposes, the numerous factions involved, and the prohibitive cost of any large scale weed eradication program (1,100 surface acres), prevented compliance with these demands. Recognizing the need for high utilization of existing recreational waters, the Virginia Commission of Game and Inland Fisheries

decided to explore the value of a limited experimental weed control program. It was hoped that with available funds fishing lanes and favorite fishing spots could be opened effectively, providing some weed free fishing areas for one or more seasons.

METHODS AND PROCEDURES

Due to the ultimate use of Chickahominy Reservoir water for human consumption, a weed control literature review and correspondence regarding the suitability of various herbicides were initiated by the Chief of the Fish Division. The literature review indicated three major methods were currently employed for the control of aquatic weeds; (1) mechanical removal, (2) manipulation of habitat so as to provide unsuitable growing conditions, and (3) chemical treatment. Mechanical removal of elodea was deemed inadvisable because of the ability of the plant's fragments to form new plants. Construction features of the dam curtailed large scale water level manipulations, even if approved by the Newport News Department of Public Utilities. Chemicals appeared to be the most practical means for controlling Brazilian elodea. However, advisability of strip treatment to open favorite fishing sites and boat lanes, the effectiveness of herbicides meeting the necessary requirements for use in a potable water supply such as Chickahominy Reservoir, proper application rates, and the lasting effect of any treatment could not be determined from available literature.

Herbicide Selection and Description

Several herbicides on the commercial market were advertised as providing effective elodea control. Although several chemicals were available, great care was required in any selective process in order to obtain chemicals that would biodegrade rapidly and would present minimal hazards to humans and other life. Newport News Department of Public Utilities officials were agreeable to shutting down their water supply pumping facilities at the reservoir if suitable short term biodegradeable herbicides could be located. It was, however, impossible to halt pumping operations for much over a week, even though water from Chickahominy Reservoir did not go directly into water lines but to a second reservoir located closer to the City. The normal daily summer pumping rate for Chickahominy Reservoir is around 22,000,000 gallons, and any long term pumping cessation would have caused dangerously low water supplies. Obviously, only a chemical or chemicals that biodegrade over very short time spans could be utilized. Voluminous correspondence with various agencies and the rejection of one herbicide resulted before unanimous agreement was reached on the suitability of two herbicides.

Exhibit 3

Diquat (Diquat dibromide (6,7 - dihydrodipyrido (1,2-a:2',1'-c) pyrazidiinium dibromide) with two pounds diquat cation per gallon, manufactured by the Ortho Division of Chevron Chemical Company, was one of the herbicides selected. According to Lawrence, et. al. (5), diquat is water soluble, stable in neutral or acid solutions, is non-volatile as the cation of dibromide salt, is rapidly absorbed when it comes in contact with soil and apparently is not released under natural aquatic conditions. Mees (6) found diquat to possess desiccative, defoliative and herbicidal properties for certain broadleaf terrestrial plants. Studies indicated phytotoxicity and degradation of diquat were influenced by light (5). Translocation of the chemical diquat takes place under darkened conditions, but plants not exposed to light show no characteristic herbicidal activities. Diquat, when in contact with plant tissue, stimulates solarization or photo-oxidative processes. This action explains why plants must be exposed to light before herbicidal activities result, desiccative properties begin and plant cells are destroyed. The speed at which plant tissue is destroyed is due to the extremely devastating activities of extended solarization. Bleaching of chlorophyll cells, oxidation of some cell constituents and excessive transpiration rates are by-products of solarization.

No deaths, differentials in growth rate or tissue changes were observed over a 24 month period in rats fed a daily ration which included 2.5 mg/kg of diquat. Acute oral LD₅₀ rates were 400-440 mg/kg diquat for rats.¹ Forty eight hour TL₅₀ rates for largemouth bass were found to be 11 ppm and 80 ppm for bluegill held in soft water (7).

Information provided on the label of diquat containers stated treated water was not to be used for human or animal consumption for 10 days following treatment. Persistence of diquat apparently varies somewhat but degradation is, nevertheless, rapid. Daly et. al. (1), while running tests on the use of diquat to control Eurasian watermilfoil in Lake Seminole, Georgia, found that diquat could only be detected in trace amounts in water treated 24 hours earlier. No traces were ever detected in soil samples. Ponds treated with diquat at the rate of 2.5 ppm had no detectable diquat residue after 7 to 14 days, according to Nicholson (8). Hogan (3) indicated laboratory tests were conducted in England to determine the persistence of diquat in aqueous solutions exposed to sunlight. Diquat was not detectable in the test containers at the end of five weeks.

Dipotassium endothall, or Potassium Endothall (3,6-endoxohexahydrophthalic acid), with an equivalent of 3.0 pounds endothall acid, was the second chemical selected. This chemical is manufactured by Agricultural Chemicals Division of Pennsalt Chemicals Corporation. To our knowledge, this was the first time the chemical was to be used for aquatic weed control in a potable water supply reservoir.

The decision to use Potassium Endothall in combination with diquat was based on the recommendation of Mr. James Parr, Representative of Pennsalt Chemical Corporation. Mr. Parr indicated experimental studies made by his organization, using a combination of diquat and potassium endothall in equal quantities, had given excellent control of elodea. His recommended application rate was 0.75 gallons of each chemical per surface acre of water (about 0.23 ppmw diquat cation and 0.17 ppmw endothall acid—based on an average depth of 5 feet). Increased coverage at a comparable price, by using the combination in

place of diquat alone, was the outstanding feature. Cost savings is immediately apparent when the retail costs of the two chemicals are compared; diquat—\$32.50 per gallon versus potassium endothall—\$16.00 per gallon.¹

Potassium endothall was not specifically cleared for use in potable water supplies but the label of this product bore a statement to the effect: "Do not use treated water for irrigation . . . within 7 days of treatment." According to the labels, potassium endothall appeared to break down into nontoxic forms even more rapidly than diquat (which listed a minimum usage time of 10 days). The Virginia Department of Health, after due deliberation, agreed to partial treatment of the reservoir using a combination of the two chemicals in the desired proportions of 50 - 50.² One of the major reasons listed by the Virginia Health Department for approving such a treatment was the fact all water from Chickahominy Reservoir had to pass through two other impounding reservoirs before reaching the City of Newport News purification plant, so the necessary seven days detention time was assured.

Literature reviews indicated application levels well above the proposed rates would be required before concentrations became lethal for fish life (7, 9). According to Meyer (7), endothall has a low toxicity for mammals. The acute oral LD₅₀ for rats was given as 35 mg/kg of body weight. Two year feeding tests showed rats could withstand up to 2,500 mg/kg of disodium salt of endothall without showing ill effects, according to the same author. Presumably, dipotassium salts of endothall would give somewhat similar results.

Potassium endothall, unlike diquat, is a contact rather than a systemic weed killer. Killing action of the chemical is relatively slow and long exposure, i.e. usage in non flowing water, is recommended. Poor results have been reported in the past when potassium endothall was the sole agent used for control of elodea (5, 7). Therefore, three possibilities can be postulated if diquat and potassium endothall used in combination give good control of elodea: 1. the amount of diquat in the combination is large enough to provide elodea control, 2. a synergistic effect occurs when the two chemicals are combined, and 3. diquat weakens the more resistant strands of elodea to the point potassium endothall becomes effective.

Applicator Selection

Bids covering strip treatment of Chickahominy Reservoir were requested from known commercial applicators, since the Commission of Game and Inland Fisheries lacked the necessary application equipment. Included in the bid requests was the specification that 150 gallons of each chemical, diquat and potassium endothall, would be provided along with personnel and equipment adequate to properly apply the materials. Responsibilities of the successful bidder were to include safe dispersion of the chemicals as well as liability, obtainment and transportation of necessary materials, and work completion within a specified period of time. Overall supervision and designation of surface areas to be treated was to remain a prerogative of the Virginia Commission of Game and Inland Fisheries (a responsibility of the senior author).

¹1967 Suggested retail price lists—Virginia.
²Personal communication to J. M. Hoffman.

The accepted bid price was \$4,877.50, or \$25.20 per acre foot of water surface to be treated. Mr. Art. Barrett,¹ Aqua Weed Control Inc., of Vienna, Virginia, and Orlando, Florida, was the successful bidder.

Pre-treatment

Approximately 200 surface acres, or about 1/6 of the existing reservoir surface, could be treated at the rate of 1.5 gallons of mix per surface acre. Linear measurements of shoreline and adjacent fishing stream lengths, courtesy of Pennsalt Chemicals Incorporation, had indicated a 100 foot strip along the reservoir's perimeter could be treated with the designated amount of chemicals. The chemical bid request also included enough materials to treat adjacent creek sections used by fishermen and the most desirable reservoir "fishing holes."

The total miles of shoreline and fishing stream lengths to be treated were broken down into subsections varying from 3/4 to 1 1/4 miles in length, using a contour map—scale 1:24,000. Subsections were terminated at distinctive landmarks easily located in the field.

Individual subsection lengths in miles, as determined by a map measurer and the aforementioned contour map, were multiplied by 12.12 to arrive at surface areas to be treated. The derived figure was then multiplied by 1.5 to arrive at gallons of diquat—potassium endosulfate required per subsection.

Once the necessary subsections had been designated and the necessary gallonage per subsection determined, the information was marked on a large scale map to speed up field applications and assure proper chemical distribution.

Marker stakes were set at the terminal points of the designated subsections one day prior to actual treatment operations. Computations were checked against actual field conditions at this time and gallonage adjustments made wherever necessary.

RESERVOIR TREATMENT

Application of the diquat-potassium endosulfate mixture commenced at approximately 10:30 A.M., July 31, 1967. A 14 foot fiberglass hulled airboat, powered by a Corvair engine, was used to apply the chemical solution. Normal boat speeds averaged 10 to 15 mph while applying the chemical solution, with refueling return speeds averaging 30 to 40 mph. Refueling distances were held to a minimum by employing a 15 foot fiberglass boat to transport chemicals as close to dispersion points as possible.

Actual chemical distribution was accomplished with a small gas powered pump which extracted the chemical-water solution from a 55 gal. drum and expelled the solution through an above-water pipe boom. The 3/4-inch diameter galvanized pipe boom was attached to the rear of the air-boat and approximately one foot above the water surface. Three nozzles, with an extreme spread between the outermost nozzles of approximately seven feet, were employed for fluid dispersion.

Calibration of the dispersal equipment was required before any large scale herbicide applications could be made. Test treatment of a subsection indicated six gallons of the 50:50 diquat-potassium endosulfate mixture per 44 gallons of water would give the necessary coverage per estimated

mile of shoreline. Once the equipment was calibrated, three passes were usually made with a minimum of two passes per 100 foot wide treatment strip. Dilution rates of herbicide versus water were changed from 6:44 to 7:43 as the applicators became more efficient and boat speeds increased.

Adjustments in treatment rates and widths covered were made to compensate for unusual field conditions encountered. Major adjustments were made in creek treatments. Application rates were increased and swath widths decreased because of the luxuriant vegetation present in side streams.

A 16.5 acre test area located along the Matahunk section of the southern shore was the last to be treated (Figure 1). Treatment of this area was completed at 8:30 P.M. on August 2, 1967. Materials for this area, consisting of pure diquat applied at the rate of one and one-half gallons per surface acre, were provided by the Ortho Division of Chevron Chemical Company.

Slightly over 200 acres of Chickahominy Reservoir were treated with 150 gallons of potassium endosulfate and 165 gallons of diquat during the three day treatment period. Approximately 5.4 surface acres were treated per hour of actual operation.

RESULTS

Treatment Termination, to 3 Days After Treatment

Areas of the reservoir treated on the first and second days could be distinguished by the presence of dead duckweed on the fourth and final day of treatment. Strands of elodea were gathered from treated areas on the final day. Discoloration and stem darkening was noted on a few of the strands.

3 to 9 Days After Treatment

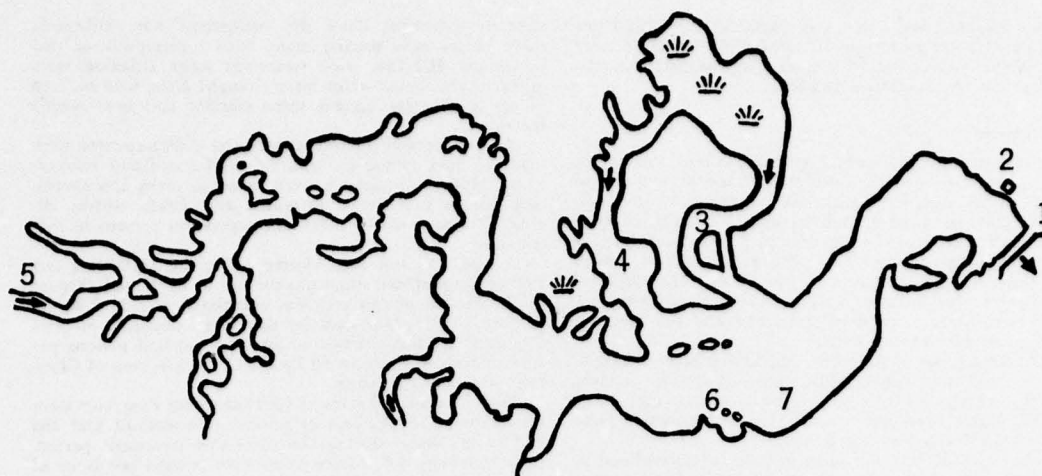
Elodea within the treated sections exhibited visible decay and reduction in abundance. Although limited, a small fish kill was reported within the 16.5 acre test area along the Matahunk shoreline of the reservoir (Figure 1). Death of the fishes was attributed to an oxygen sag caused by rapid decomposition of dead elodea and was not unexpected due to the size of the treated area and the luxuriant elodea growth.

The creeks were heavily infested with elodea and a marked oxygen sag along with an appreciable fish dieoff had been anticipated, even though less than one-half of the total surface area of each creek was treated. However, fish kills within the main fishing streams, Lacey and Johnson creeks, were extremely light.

11 Days After Treatment

An extensive survey of the treated fishing lanes was made 11 days after final application. For the most part, no elodea was visible in the lanes treated along the reservoir proper. Partial wind drift of still living elodea was evident along the Matahunk shoreline. Portions of the fishing lane along this shoreline, as well as the shoreline portion of the test area, were completely choked. Drifting was attributed to an incomplete kill of isolated elodea strands along the periphery of fishing lanes and the test area. Prevailing wind action, coupled with partial disinte-

¹Now President, National Weed Service, Orlando, Florida.



1000 0 1000
FEET

Figure 1

- | | |
|--------------------|----------------------|
| 1. Dam | 5. Major Inlet |
| 2. Pumping Station | 6. Cypress Point |
| 3. Johnson Creek | 7. 16.5 A. Test Area |
| 4. Lacey Creek | |

gration of the strands, concentrated the still living elodea along the shoreline.

Occasionally, strands of living elodea could be dredged up from the reservoir bottom in all fishing lanes, both on the reservoir proper and in the treated side streams. No live strands could be dredged from the central portion of the test area treated with straight diquat. Peripheral portions of the test area did have isolated strands of elodea present. Since live strands were found along the periphery, lack of vegetation in the central portion was not attributed to the increased effectiveness of diquat used alone. Nonetheless, the value of large scale applications was clearly pointed out.

Fishing lane clearance within Lacey and Johnson creeks was somewhat erratic despite threefold increases in the application rates (swath widths were purposely narrowed in order to increase herbicide levels). Despite the fact that water movement could not be detected in side streams, chemical drift from treated to untreated portions was observed. Midstream clearance of elodea increased with downstream distance. Observations indicated partial elodea clearance in the sprayed, but drift-affected, lanes had occurred, although unsprayed mid-channel areas were paradoxically cleared.

Treatment of luxuriant elodea growths in shallow side guts and coves of Lacey and Johnson creeks, along with some unnamed side streams, illustrated poor to fair clearance. The guts and coves received very close to the recommended rate of 1.5 gallons herbicide per surface acre. It was assumed that poor control in the peripheral areas was

at least partially due to heavy silt accumulations. Silt deposits were clearly visible on all vegetation of the protected areas.

Complete elodea clearance from the treated areas had not resulted by this observation date, but all major fishing lanes and fishing spots were clear enough to allow free passage of boats.

15 Days After Treatment

Observations made on the fifteenth day following treatment were nearly identical with those of the eleventh. Elodea was less visible in some lanes. Intermittent strands of live elodea were dredged from all but the central portion of the 16.5 acre test area.

34 Days After Treatment

All fishing lanes were clear and free of elodea except for the lower end of Lacey Creek and the upper portion of Johnson Creek. Floating but unattached vegetation was present in these regions. Astonishingly, both treated and untreated portions of the reservoir were cleared of all but a few intermittent strands of elodea. The only exception was the uppermost end of Chickahominy Reservoir. Judging from local reports, the major "dieback" developed approximately one week prior to this inspection and had been immediated preceded by approximately one week of heavily overcast and rainy weather. Widespread "dieback"

throughout Chickahominy Reservoir, both in treated and untreated portions, gave rise to the possibility that the "dieback" was due to natural causes. Later evidence refuted this finding. It is more likely that conditions were optimal at the time of treatment and that chemical dispersion gave rise to concentrations strong enough to provide lethal dosage rates in untreated areas. Guppy (2) reported ideal clearance of a lake infested with Florida elodea (*Hydrilla verticillata*), which was treated in the month of November using Aquathol Plus (which contains Potassium Endothall as one of the major ingredients). July treatments in the same water had no effect.

Living strands of elodea were dredged from both treated and untreated portions of the reservoir with one exception, the central portion of the large test area.

213 Days After Treatment

No elodea could be dredged from treated and untreated areas in water depths exceeding 5.5 feet. Occasional strands of live elodea were dredged in all sections having depths between one to five feet. Dredged strands were approximately 4 to 12 inches in length and showed no signs of new growth.

Small quantities of coontail (*Ceratophyllum* sp.) and one strand of bladderwort (*Utricularia* sp.) were dredged from the cypress tree region of the reservoir. (Figure 1) Fairly large quantities of coontail were dredged from Lacey Creek on the North side of the Reservoir. Abundance of this species in Lacey Creek increased with upstream distance. Coontail was dredged from shallow regions down to depths of approximately seven feet.

261 Days After Treatment

The abundance and depth distribution of elodea was relatively unchanged from the previous observation. Strands did appear to be more abundant in the upper untreated portion of the reservoir.

New growth on old strands was visible and surface water temperature was 61°F. at the time of visitation. Strands from the treated sections averaged 53 mm of new growth, while strands from the upper and untreated section illustrated approximately twice as much new growth.

Coontail was found in several portions of the reservoir inhabited by dense growth of elodea (prior to strip treatment) when inspection trips were made in the Spring of 1968. The possibility exists that coontail would constitute a replacement species if control measures were continued.

319 Days After Treatment

A comprehensive check of the reservoir led to several important findings. Extensive concentrations of phytoplankton were visible in all portions of the reservoir. The palm of one's hand could not be detected when one's arm was submerged to elbow depth. Luxuriant growth of elodea, averaging 29 to 38 inches in length, were found in the uppermost part of the reservoir far removed from the sites of original treatment. The few strands of elodea dredged up in other areas of the reservoir were confined to depths of approximately 3.5 feet or less, and averaged 9 to 15 inches of new growth.

Fewer strands of elodea were dredged up on this trip than on previous visitations. No strands were obtained

from the Cypress Point region where strands had been obtained on all former trips. It was felt the reduction in strands was due to the heavy shading provided by the extensive phytoplankton "bloom."

Coontail infestations were unchanged from the previous visitation. If anything, coontail concentrations were more extensive than formerly and were still found in depths down to 7 feet in depth.

Oxygen concentrations were found to be around 10 ppm in the reservoir proper. The upper end of one flooded and unnamed creek on the South side of the reservoir had only 0.6 ppm oxygen present. Decay of vegetation, along with the smell of swamp gas, was apparent.

SUMMARY

Chickahominy Reservoir, a source of potable water, was strip treated with herbicides in order to open up fishing lanes and to provide "fishing holes" within extremely dense growth of Brazilian elodea (*Egeria densa*). Contrary to expectations, the strip treatment of approximately 200 surface acres of the reservoir resulted in freeing nearly 900 surface acres of the reservoir from elodea. Since water from the 1,100 surface acre reservoir was used for drinking purposes, an intensive search for suitable herbicides was made prior to treatment operations. Diquat and potassium endothall combined, in equal quantities and applied at the combined rate of 1.5 gallons per surface acre, were selected as the elodea controlling chemicals. Degradation of these chemicals to non-toxic forms was considered rapid enough under the circumstances to safely permit treatment of approximately 1/6 of the reservoir.

Slightly over 200 surface acres of the reservoir were treated with 150 gallons of potassium endothall and 165 gallons of diquat during a three day treatment period. An airboat with an above water boom was used to apply the herbicides (Figure 2).

Elodea infestations were reduced enough that boat passage was possible in all major fishing lanes and areas on the eleventh day following final application. Erratic chemical drift and elodea control was experienced on a short term basis in the almost non-flowing side streams. Partial clearance in treated lanes and areas, enough to allow free



Figure 2. Strip treatment application of diquat-potassium endothall to control the growth of elodea in Chickahominy Reservoir, a source of municipal water. Photo by Mr. Max Alior, Richmond Times Dispatch.

boat traffic, had been effected by the 15th day following final treatment. The entire reservoir was cleared of elodea by the 34th day following final application. Although treatment concentrations were considered low even for the 200 acres treated, the concentrations appeared to be strong enough to clear all but the uppermost end of the 1,100 surface acre reservoir. Because live strands of elodea were found in nearly all portions of the treated sections, return of vegetation to former levels may occur within two years following treatment unless phytoplankton populations provide enough shade to prevent regrowth.

CONCLUSIONS

1. Clearance of major fishing lanes and favorite fishing sites in the main reservoir was relatively successful within 1.5 weeks of treatment. The basic treatment rate was 0.75 gallon of diquat and an equal amount of potassium endothall per surface acre.
2. Most creek sections were heavily infested with elodea and were treated at rates above the recommended 1.5 gallons herbicide per surface acre. Elodea reduction in these sections was considered fair to good. Short term treatment success in the creek sections was not directly proportionate to an increase in application rates, implying factors other than concentration were involved.
3. Shallow protected coves and guts treated at the rate of 1.5 gallons diquat-potassium endothall per surface acre gave ineffective control initially, but by the 34th day nearly all of these regions had been cleared.
4. Herbicide applied in fishing lanes within Johnson and Lacey creeks exhibited an erratic drift towards deeper water despite any visual evidence of water movement. Weed kill within the drift affected lanes was incomplete until approximately 30 days had elapsed, but clearance of the deep water sections was more rapid.

5. Complete "dieoff" of elodea was not achieved except in the central portion of a large test area treated with diquat applied at the rate of 1.5 gallons per surface acre. Clearance in the central area was attributed more to increased effectiveness of large scale applications than to the use of pure diquat.
6. Reinfestation of the treated areas within two years can be anticipated if the present phytoplankton population levels decline to the levels of pre-treatment.
7. Coontail (*Ceratophyllum* sp.) may act as a replacement species for elodea, perhaps becoming as much of a nuisance as elodea in previous years.

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COMMONWEALTH OF VIRGINIA



VIRGINIA INSTITUTE OF MARINE SCIENCE

GLOUCESTER POINT, VIRGINIA 23062

February 18, 1972

Mr. W. H. Tamm, Chief
Engineering Division
Corps of Engineers
803 Front St.
Norfolk, Virginia 23510

Dear Bill:

This letter is in response to your request for comments
on the Walker Dam Impoundment - Aquatic Plant Control Project.

I have reviewed the proposed control project and believe
that if the control is attained substantial benefits will result.
The only concern of the Institute would be to make certain that
no release of the lake water be made to the Chickahominy River
while the herbicide is still active. Extensive damage to the
marsh lands in the Chickahominy could result if such a release
was made.

Sincerely,

M. E. Bender, Ph.D.
Assistant Director

MEB/jh

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WASHINGTON, D.C. 20250

OFFICE OF ADMINISTRATOR

March 16, 1972

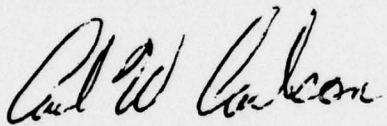
Mr. W. H. Tamm
Chief, Engineering Division
Corps of Engineers
Department of the Army
Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510

Dear Mr. Tamm:

The draft environmental statement on "Walker Dam Impoundment
Aquatic Plant Control Project, New Kent County, Virginia,"
has been reviewed by the Agricultural Research Service staff.

We are enclosing two copies of our comments concerning this
draft statement.

Sincerely,



Carl W. Carlson
Acting Deputy Administrator

Enclosure

ARS Comments on the Draft Environmental
Statement entitled "Walker Dam Impound-
ment Aquatic Plant Control Project,
New Kent County, Virginia"

We have reviewed the subject Impact Statement and found it to be factual and quite complete.

All of the data presently available make it appear very unlikely that any permanent or long term deleterious effect will occur from this use of the herbicides diquat and endothall. The long term benefits are as described in the statement.

We believe that testing the water for the presence of herbicides prior to resumption of its use for domestic purposes is advisable. While there is ample evidence that diquat and endothall are rarely present in measurable quantities between 7 to 10 days following treatment, it is difficult to refute contentions that they might have been present unless actual analytical data are at hand.

The statement does not make entirely clear whether the intent is to treat the entire 1100 acre impoundment, or only part of it as was done in 1967. If the entire body of water is treated at one time, then it probably should be done before the maximum quantity of plant material is present, and before the water temperature becomes high. This may aid in preventing excessively severe anaerobic conditions and an unacceptable level of fish kill. An alternative would be to treat portions or strips of the impoundment as before. Even though the entire body of water is effected eventually, the immediate result is to reduce the level of anaerobiosis, and to extend it over a longer period.

While we do not concur in the belief that endothall is effective on egeria, nor that a rather long exposure time is required, the mixture does have the advantage of being more economical than diquat alone. Egeria is very susceptible to diquat, while most of the other weeds mentioned are readily controlled with endothall. Both herbicides have the advantage of short periods of persistence in water.

There is little likelihood of injury to the forest nursery plantings located near the upper reaches of the impoundment. The influx of water from the river should serve to clear this area of herbicide residues first. If use of the water at this point is postponed for several days, no problems should arise.

One item overlooked in the statement is the possible loss of food for wildfowl by the destruction of some species such as pondweeds. This loss would be most severe during the year in which the treatment is made. These species do not compete well with egeria and probably would be as abundant, or more abundant than originally, during a period of several years following the treatment with herbicides.

Egeria and Elodea were at one time generic synonyms. The Weed Science Society of America now recognizes Egeria densa Planch. as the correct Latin name and egeria as the common name for what was frequently referred to in the past as Brazilian waterweed. Elodea canadensis Michx. and elodea are now the Latin and common names accepted by WSSA for the plant formerly referred to as waterweed. These standardized names should be used in the Impact Statement.

We hope that our comments concerning the Impact Statement are useful to you.



United States Department of the Interior
BUREAU OF OUTDOOR RECREATION
SOUTHEAST REGIONAL OFFICE
810 New Walton Building
Atlanta, Georgia 30303

IN REPLY REFER TO:

E3033

March 13/72

Colonel James H. Tormey
District Engineer
U.S. Army Engineer District,
Norfolk
803 Front Street
Norfolk, Virginia 23510

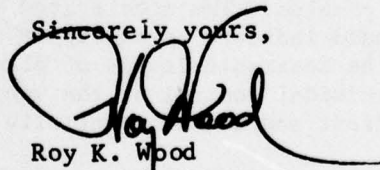
Dear Colonel Tormey:

This is in response to Mr. J. R. Philpott's letter of January 31, 1972, (reference NAOEN-R) requesting our review and comments on a draft environmental statement pertaining to an aquatic plant control project at the Walker Dam Impoundment in New Kent County, Virginia.

The draft appears to objectively discuss the impact of the proposed action upon resources containing recreation values, their use, and the related environment.

From information contained in the statement, we conclude the proposed action would not have significant effect in those areas of our responsibility.

Sincerely yours,



Roy K. Wood
Regional Director



U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION III

6th & Walnut Sts., Philadelphia, Pennsylvania 19106

April 5, 1972

Mr. W. H. Tamm, Chief
Engineering Division
Department of the Army
Norfolk District, Corps of Engineers
Fort Norfolk
803 Front Street
Norfolk, Virginia 23510

Dear Mr. Tamm:

This is in response to your January 31, 1972 NAOEN-R letter which enclosed a draft environmental impact statement for our review and comment in regard to Walker Dam Impoundment, Aquatic Plant Control Project, New Kent County, Virginia.

As a result of this review, the following is offered for your consideration.

It would seem that the most logical course of action (not mentioned in the environmental impact statement) is that of considerably reducing the amount of nitrates and phosphates entering the reservoir. Upstream waste treatment plants could be controllable point sources of nutrients, thus reducing accelerated eutrophication in the impoundment. Nutrient control rather than plant control is a more logical approach to the aquatic plant problem. The accelerated eutrophication in the Walker Dam Impoundment would indicate an excess of nutrients beyond the levels compatible with the desirable levels of plantlife in the lake. Any harvesting or herbicidal control of the weed population in the lake would be a temporary effect and not substantially affect the causes of the problem.

If the Elodea plants are destroyed and the sources of nutrients are not removed, the lake may become infested with blue-green algae. This would present a greater problem by affecting water supplies and aesthetics. Such an occurrence has been documented for Lake Zoar, Connecticut. Similar patterns of change have occurred in the tidal freshwater Potomac River. Blue-green algae present a tremendous management problem for taste

and odor control in water supplies. Rather than the proposed after-the-fact methods of aquatic plant control, we strongly recommend that a nutrient source control program be thoroughly investigated as an alternative to the proposed action for the Walker Dam Impoundment.


Since Elodea establishes first in shallow areas of an impoundment, it is suggested that a concerted soil erosion program be established in the Chickahominy River Watershed to control siltation.

There is no residue tolerance for either diquat or endothal in water or fish. Residue tolerances in fish should be established before fishing is permitted after spraying. Spraying should be performed only on days when winds are of such velocity that the spray will not harm desirable vegetation, and conducted in limited sections of the impoundment at specified time intervals so as not to seriously deplete the dissolved oxygen in the reservoir. There should be a constant surveillance of the sprayed sections to ensure that detrimental effects are not occurring or have occurred.

Neither diquat nor endothal are registered for use in potable water. The USDA Summary of Registered Agricultural Pesticide Uses (3rd edition) lists the following registration restrictions, which were not included in this project: "Do not use for human or animal consumption or crop spraying for ten days after treatment."

Thank you for the opportunity to comment on this draft environmental impact statement. Our technical staff is available to discuss this proposal with you if further assistance or clarification of these comments is necessary.

Sincerely yours,



Robert J. Blanco, Acting Chief
Environmental Impact Statement Branch



Commonwealth of Virginia
STATE WATER CONTROL BOARD

P. O. Box 11143, 4010 W. Broad St., Richmond, Virginia 23230 (703) 770 2241
A. H. Paessler, Executive Secretary



BOARD MEMBERS

Norman M. Cole, Jr.
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W. H. Singleton
Robert W. Spessard

May 9, 1972

Department of the Army
Norfolk District Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510

Re: NAOEN-R

Dear Sirs:

We have reviewed the Draft Environmental Statement dated January 20, 1972, on Walker Dam Impoundment - Aquatic Plant Control Project, New Kent County, Virginia prepared by the U. S. Army Engineer District, Norfolk, Virginia and Virginia Commission of Game and Inland Fisheries, Richmond, Virginia.

We are enclosing a copy of Minute 46 of the November 26, 1963 Board meeting giving a "Policy Statement Regarding Purposeful Introduction of Chemicals into Virginia State Waters for the Control of Aquatic Vegetation or Animals."

The Draft Environmental Statement indicates that the "Aquatic Plant Control Project" could violate the Board's policy statement by making the waters in the Walker Dam Impoundment "directly or indirectly detrimental to the public health", "damages or interferes with sport or commercial fishery", "unsuitable as a source of water supply" and "unsuitable for recreational and other uses" for at least a short period of time. The chemicals to be used, as described in the statement, apparently will not cause any long term dangers.

The Board's policy statement prohibits our approval of the "Aquatic Plant Control Program". We believe, however, that the project could be carried out providing agreement can be reached on discontinuing the use of the impoundment waters for public water supplies so long as the herbicide chemicals are detectable. We also feel that the lake should be closed to fishing and other recreational uses for at least a week following treatment and, of course, water containing the herbicides should not be used for irrigation. We assume that personnel of the Commission of Game and Inland Fisheries will be responsible for the application of the herbicide and that the commission will assume the

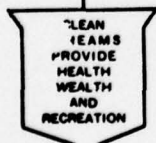


Exhibit 8

Department of the Army
Page 2
May 9, 1972

responsibility for replacement of any fish that may be killed, if, in their opinion, such replacement is necessary or desirable.

We would appreciate being kept advised of the progress of this project and of its effects on the aquatic plants and the waters of the impoundment.

Very truly yours,



R. V. Davis
Assistant Executive Secretary

JLH/jgm

cc: Commission of Game & Inland Fisheries

Minute: 46
Board Meeting:

November 26, 1963

Minute 46 - Policy Statement Regarding Purposeful Introduction of Chemicals into Virginia State Waters for the Control of Aquatic Vegetation or Animals

At its meeting on September 27, 1963, the Board, after considerable discussion, tentatively adopted a policy statement concerning the use of chemicals to control aquatic vegetation and animals and directed the staff to submit it to various persons and other State agencies for comments and review. After reviewing the suggested changes that were received, the Board adopted the statement in final form. as follows:

"The Water Control Board hereby gives notice that any person who introduces directly into State waters any chemical for the purpose of controlling aquatic vegetation or animals, and who thereby makes such State waters directly or indirectly detrimental to the public health, or damages or interferes with a sport or commercial fishery in such State waters; or who thereby makes such State waters unsuitable as a source of water supply, or unsuitable for recreational and other uses; is guilty of violating the State Water Control Law and may be prosecuted for such violation."

The Board directed the staff to give the policy statement wide distribution to interested parties.



THE ASSISTANT SECRETARY OF COMMERCE
Washington, D.C. 20230

May 8, 1972

Mr. W. H. Tamm, Chief
Engineering Division
U. S. Department of the Army
Corps of Engineers
Fort Norfolk
803 Front Street
Norfolk, Virginia 23510

Dear Mr. Tamm:

The draft environmental statement for the "Walker Dam Impoundment Aquatic Plant Control Project, New Kent County, Virginia," which accompanied your letter of January 31, 1972, was received by the regional office of the Department of Commerce for review and comment.

The Department of Commerce has reviewed the proposal and feels that the environmental impact statement provides a good project description and addresses major environmental topics adequately. Recognition of the basic factors responsible for the elodea problem and of the efforts to deal with root causes is a commendable aspect of the statement.

We hope these comments will be of assistance to you and apologize for the delay in responding to your request.

Sincerely,

A handwritten signature in cursive script, reading "Sidney R. Galler", is written over the typed name.

Sidney R. Galler
Deputy Assistant Secretary
for Environmental Affairs

CONSERVATION COUNCIL of VIRGINIA, Inc.

200 West Grace Street
Richmond, Virginia 23203

William T. Reed, III
President
P. O. Box 177
Manakin-Sabot, Va. 23103

Matthias E. Kavhne
Vice President
School of Architecture
University of Virginia
Charlottesville, Va. 22901

Elizabeth Hartwell
Secretary
796 Bolling Drive
Alexandria, Va. 22308

J. Robert Hicks
Treasurer
7625 Marilee Road
Richmond, Va. 23225

March 27, 1972

ARTICIPATING ORGANIZATIONS

Alleghany Crusade
for Clean Air
Association for the Preservation
of Virginia Antiquities
Canoe Cruisers Association
Citizens Against Pollution
(Hampton Roads)
Citizens Committee for the
Virginia Outdoors Plan
Citizens Committee for
Virginia State Parks
Citizens Council for a
Clean Potomac
Council for Environmental
Quality (Hampton Roads)
ECOS
Fairfax County Federation of
Citizens Associations
Great Falls Conservation
Council
League of Women Voters
of Virginia
Metropolitan Washington
Coalition for Clean Air
North River Riparian
Association
Northern Virginia Conservation
Council
Northern Virginia Student
Environmental Council
Professional Chapter, American Society
of Landscape Architects
Rappahannock League for
Environmental Protection
Reclaim the James
Richmond Scenic James Council
~~James~~ Audubon N.S.
Southeast Chapter, Sierra Club
The Garden Club of Virginia
Upper New River Valley
Association
Virginia Anglers Club
Virginia Chapter, American
Institute of Architects
Virginia Chapter, American
Institute of Planners
Virginia Chapter, The Nature
Conservancy
Virginia Citizens Planning
Association
Virginia Division, American Association
of University Women
Virginia Division, Izaak Walton
League
Virginia Farm Bureau
Federation
Virginia Federation of
Garden Clubs
Virginia Federation of
Women's Clubs
Virginia Outing Club
Association
Virginia Region, National
Speleological Society
Virginia Society of
Ornithology
Virginia Subsection, Society
of American Foresters
Virginia Trails Association
Wilderness Committee
Wilderness Society
Wise County Conservation
Council
Zero Population Growth
of Virginia

Chesapeake Bay Foundation

Working for the conservation (preservation and/or wise use) and appreciation of Virginia's natural and historic resources.

Mr. W. H. Tamm
Chief, Engineering Division
Department of the Army
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510

Dear Mr. Tamm:

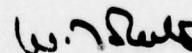
I appreciate your letter of January 31,
1972, enclosing the draft environmental statement
for the Walker Dam Impoundment Aquatic Plant Con-
trol Project, New Kent County, Virginia.

The Conservation Council of Virginia has
reviewed this draft environmental statement and
sees no basis on which to take issue with the pro-
posed action.

The project appears to us to have been
carefully thought out, and we doubt that any harm
will result from the proposal.

Thanking you for the opportunity to comment
on this draft, I am

Sincerely yours,



William T. Reed, III

WTRIII:cw

Exhibit 10

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best available copy.

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